

WATER RESOURCES TECHNICAL REPORT

MONTANA STATEWIDE OIL AND GAS ENVIRONMENTAL IMPACT STATEMENT AND AMENDMENT OF THE POWDER RIVER AND BILLINGS RESOURCE MANAGEMENT PLANS

Prepared for:

U.S. DEPARTMENT OF INTERIOR BUREAU OF LAND MANAGEMENT MILES CITY FIELD OFFICE

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Acronyms

ac-ft acre-feet

bgs below ground surface

BLM Bureau of Land Management
BIA Bureau of Indian Affairs
BWPD barrels of water per day

CBM Coal bed methane CO₂ Carbon Dioxide

EIS Environmental Impact Statement

EPA U.S. Environmental Protection Agency

ESP electric submersible pump

ft² square foot

gpm gallons per minute

hp horsepower

MBMG Montana Bureau of Mines and Geology

MBOGC Montana Board of Oil and Gas Conservation

MDEQ Montana Department of Environmental Quality

MDNRC Montana Department of Natural Resources and Conservation

MPDES Montana Pollutant Discharge Elimination System

m/gL milligrams per liter

mi² square mile

NEPA National Environmental Policy Act

NPDES National Pollutant Discharge Elimination System

PRB Powder River Basin
psi pounds per square inch

RFD Reasonable Foreseeable Development

RMP Resource Management Plan
RMA Resource Management Area
SAR Sodium Adsorption Ratio

SJB San Juan Basin
TCF Trillion Cubic Feet
TDS total dissolved solids

2-D two-dimensional3-D three-dimensional

USGS U.S. Geological Society

CHAPTER 1 – BACKGROUND

INTRODUCTION

During the second half of the 1990s, coal bed methane (CBM) production increased dramatically nationwide to represent a significant new source of natural gas to meet ever-growing energy demands. In Montana, oil & gas development has been growing since the first oil wells were drilled in the early 20th century. Today, Montana's oil and gas industry exceeds 300 million dollars per year and is a significant aspect of the state's economic livelihood. Recent oil and gas exploration and development in the state has included a focus on CBM exploration and development. There are currently more than 200 commercially producing CBM wells in the state of Montana, all of which are located in the Powder River Basin near the town of Decker, Montana. CBM development in the Montana portion of the Powder River Basin (PRB) is in part a result of successful development in the Wyoming portion of the basin where CBM activity started as early as 1993 (Flores et al, 2001).

A primary intent of the Montana CBM Environmental Impact Statement (EIS)¹ is to provide an overall projection of impacts associated with CBM development for the planning areas and to address issues raised as part of the public scoping process. Of primary consideration for the EIS are water resources. Due to the extraction methods required for CBM production, impacts can potentially result from CBM development. The purpose of this Water Resources Technical Report is to serve as one of many supporting documents for the subject EIS.

PUBLIC SCOPING ISSUES

During the scoping process for the Montana CBM EIS, the public was provided with the opportunity to review and comment on resource issues identified as important by the Bureau of Land Management (BLM) and the State of Montana. The public was also provided an opportunity to identify new issues and comment on the Draft Planning Criteria. During the public comment period, more than 2,100 comments in more than 300 separate responses were received (ALL, March 2001). Of those comments, more than 850 related to water resource issues. Water issues raised through the public scoping process are summarized below:

Groundwater Quality and Quantity

This category of comments pertains to the effects of CBM development on groundwater quality and quantity. A total of 140 comments were received in this category. A number of comments suggested that CBM pumping would degrade groundwater quality. Other comments made note of possible cumulative effects resulting from CBM pumping, and requested that cumulative groundwater impacts be included in the study. Several comments expressed concern that CBM pumping would deplete the quantity of groundwater. Additionally, concerns were expressed that groundwater aquifers would be contaminated from either open boreholes (artificial penetrations) or saltwater pumped from the ground. Several comments were also received that called for 3-D modeling to be performed as a means of predicting impacts to groundwater.

Surface Water Quality and Availability

A total of 198 comments were received that dealt with surface water quality and availability. Comments concerning the impact to surface water from CBM discharge were the most prevalent (129 comments). Other comments questioned the cumulative/long-term effect as a result of discharge of CBM water (54 comments). Several respondents expressed concern about CBM discharge water coming from Wyoming and the resultant impacts on Montana surface waters. Other comments mentioned in this section include interest in decreased surface water availability, and concerns about the wasting of groundwater as a resource.

Wastewater Disposal and Discharge

This category of comments pertains to the disposal and discharge of water from CBM production. A total of 97 comments were received. Comments in this section included siltation of rivers from increased flows, treatment of discharged water, landowner input into discharge on his/her land, and questions related to the injection of discharged water. The two most prevalent comments concerned: 1) The re-injection of wastewater into the same

¹ The BLM and State of Montana are currently preparing an Environmental Impact Statement for CBM development and development of conventional oil & gas. However, the development of CBM is a primary factor of this document.

formation rather than surface disposal (42 comments); and 2) The suitability of the discharged water for livestock and agricultural use.

Water Conservation

Water conservation issues were the most common comment received during the scoping process. A total of 260 comments were received that dealt with water conservation. The water conservation topics covered aquifer drawdown and recharge, water replacement cost, permitting questions, and the wasting of water resources. The two most common comments were: 1) Water recovery wells will go dry due to a lowered water table as a result of CBM development (119 comments); and 2) Aquifer recharge rates will be affected due to CBM development (90 comments). On the evidence of the comments, there was a particular interest concerning the fate of private water wells under the influence of CBM development. Based on review of the scoping comments, it is evident that public groundwater concerns exist in many areas of the state, but are most acute in the Powder River Basin (PRB).

Water Rights

A total of 67 comments were received that discussed the issue of water rights. Most of the comments were questions on the CBM use of groundwater without obtaining the rights to produce the water. Several comments reviewed suggested the need for the Environmental Impact Statement (EIS) to ensure that water rights and/or groundwater resources would be protected.

Groundwater Resource Assessment

There were 78 comments that recommended the preparation of a groundwater resource assessment. Over half of the comments (55 comments) stressed the need to gather baseline data on all groundwater resources prior to development of CBM. The second most prevalent comment (14 comments) was a request to prepare a threedimensional (3-D) map of all the aquifers in the project area. Other comments included the need for a regional water plan and development of a groundwater resources database.

STUDY AREA

The planning area for the EIS is defined as the area where oil and gas decisions will be made by the BLM and the State of Montana. The BLM's planning area is the oil and gas estate administered by the BLM in the Powder River and Billings Resource Management Planning (RMP) areas. The State of Montana's planning area is statewide, with emphasis on the state-administered oil and gas within the BLM planning area and in Blaine, Park and Gallatin counties. The planning area excludes those lands administered by other agencies (for example, Forest Service and Tribal Councils).

For ease of reference, the Billings and Powder River RMP areas, and Blaine, Park, and Gallatin counties, are referred to in the document as the BLM and State "CBM emphasis area." This is the 16-county area within the BLM and state planning area where CBM development interest has been identified.

The Powder River RMP area encompasses the southeastern corner of Montana, including Powder River, Carter, and Treasure counties, and portions of Big Horn, Custer, and Rosebud counties. The Powder River RMP area comprises approximately 1,080,675 acres of federally managed surface and 4,103,700 acres of federal mineral estate.

The Billings RMP area comprises the south-central portion of Montana consisting of Carbon, Golden Valley, Musselshell, Stillwater, Sweet Grass, Wheatland, and Yellowstone counties and the remaining portion of Big Horn County. The Billings RMP area comprises approximately 425,336 acres of federally managed surface and 906.084 acres of federal mineral estate.

Adjacent to the planning areas, other major land holdings include the Crow, Northern Cheyenne and Fort Belknap Indian Reservations, the Custer National Forest, portions of Yellowstone National Park, the Big Horn Canyon National Recreational Area, the Burlington Northern and Santa Fe Railroad, and the Fort Keogh Agricultural Experiment Station. The total surface area of the CBM emphasis area (all owners) exceeds 25 million acres.

Although a CBM emphasis area has been identified for purposes of the EIS and Resource Management Plan (RMP) Amendment, the primary area of concern identified during the public scoping process is the PRB of Montana. The Montana PRB is also the area where CBM development is expected to be most intense. For the purposes of this Technical Report, analyses will primarily focus on the Montana portion of the PRB. Exhibit 1 is a map showing the

entire state of Montana, the CBM emphasis area, and other points of interest for reference throughout the remainder of this report.

REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

To facilitate planning and the determination of potential environmental consequences, the BLM prepared a Reasonable Foreseeable Development (RFD) scenario. The RFD predicts oil and gas development in five areas: the Powder River RMP area, the Billings RMP area, and in Blaine, Gallatin, and Park counties of Montana. The RFD projects drilling of both conventional and CBM wells, numbers of pipelines, and compressors needed for production of CBM wells.

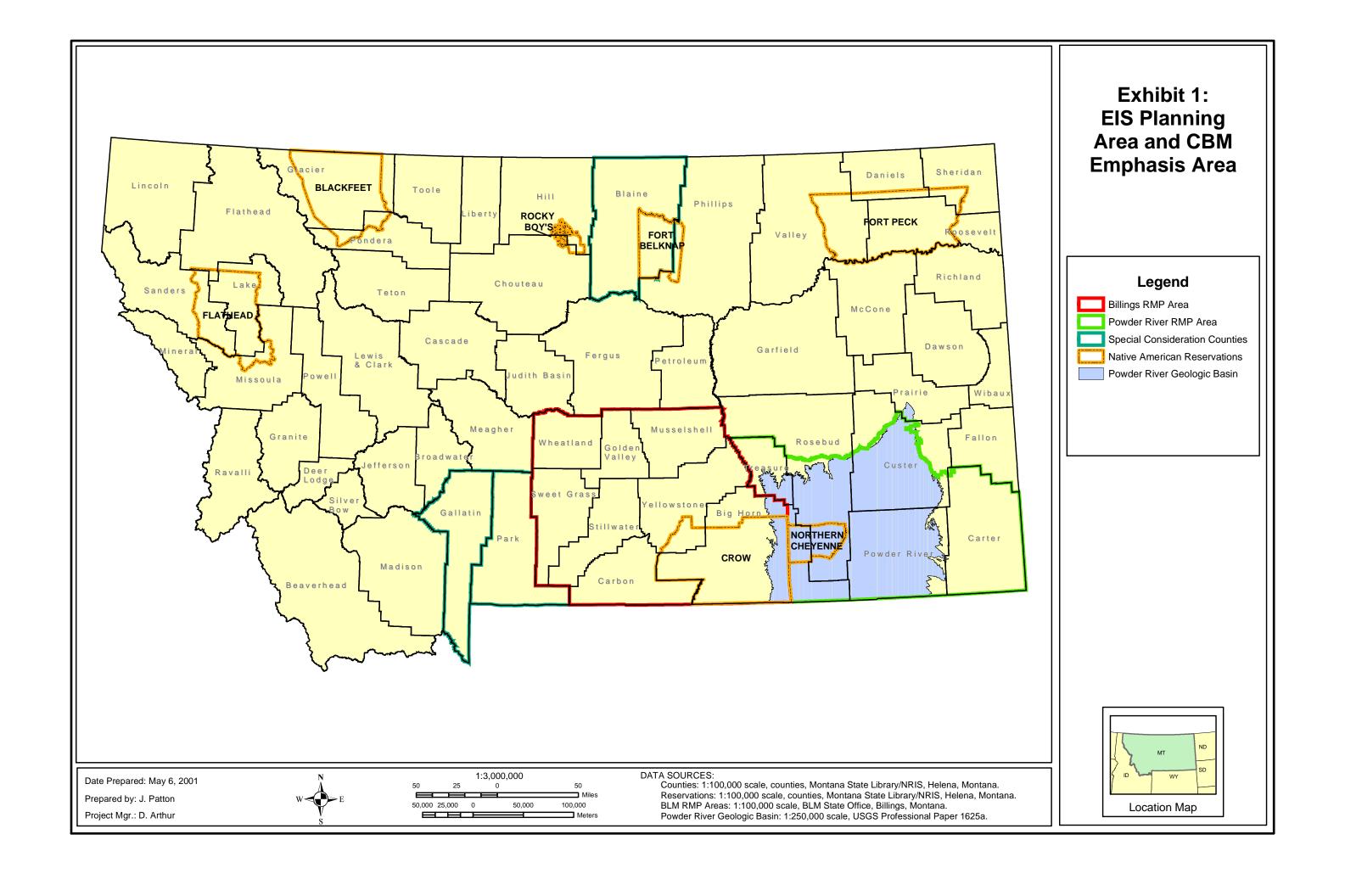
For CBM exploration and development, the areal extent of certain coals and the rank of coals in the study areas were considered. Areas of sub-bituminous to bituminous coals were considered as most likely to be explored and developed in Montana, although exploration and development has occurred mainly in sub-bituminous coal in the Wyoming portion of the Powder River Basin. The USGS produced a map showing the areas of coal, by rank, for the United States. This information indicates sub-bituminous and bituminous coals in many parts of the study area. Powder River, Rosebud, Custer, and Big Horn counties contain the northern part of the Basin, which extends north from Wyoming. Blaine and Musselshell counties have mostly sub-bituminous coal. Carbon County has an extension of the Big Horn Basin coal, which is ranked as bituminous coal. Gallatin and Park counties have scattered areas of bituminous to sub-bituminous coals. The projection of methane gas to be produced from coal beds in Montana range from a low of 1 TCF (Fred Crockett-PRB est -RMG, Casper) to a high of 17.7 TCF (estimated based on figures from Nelson, 2000). This and other information for Montana was used to predict where CBM exploration is most likely to occur in the emphasis area. The RFD predicts the number of CBM wells that would be drilled and completed during the next 10 to 20 years. For CBM, potential development in the RFD was estimated to be as much as approximately 26,000 wells in the next 20 years.

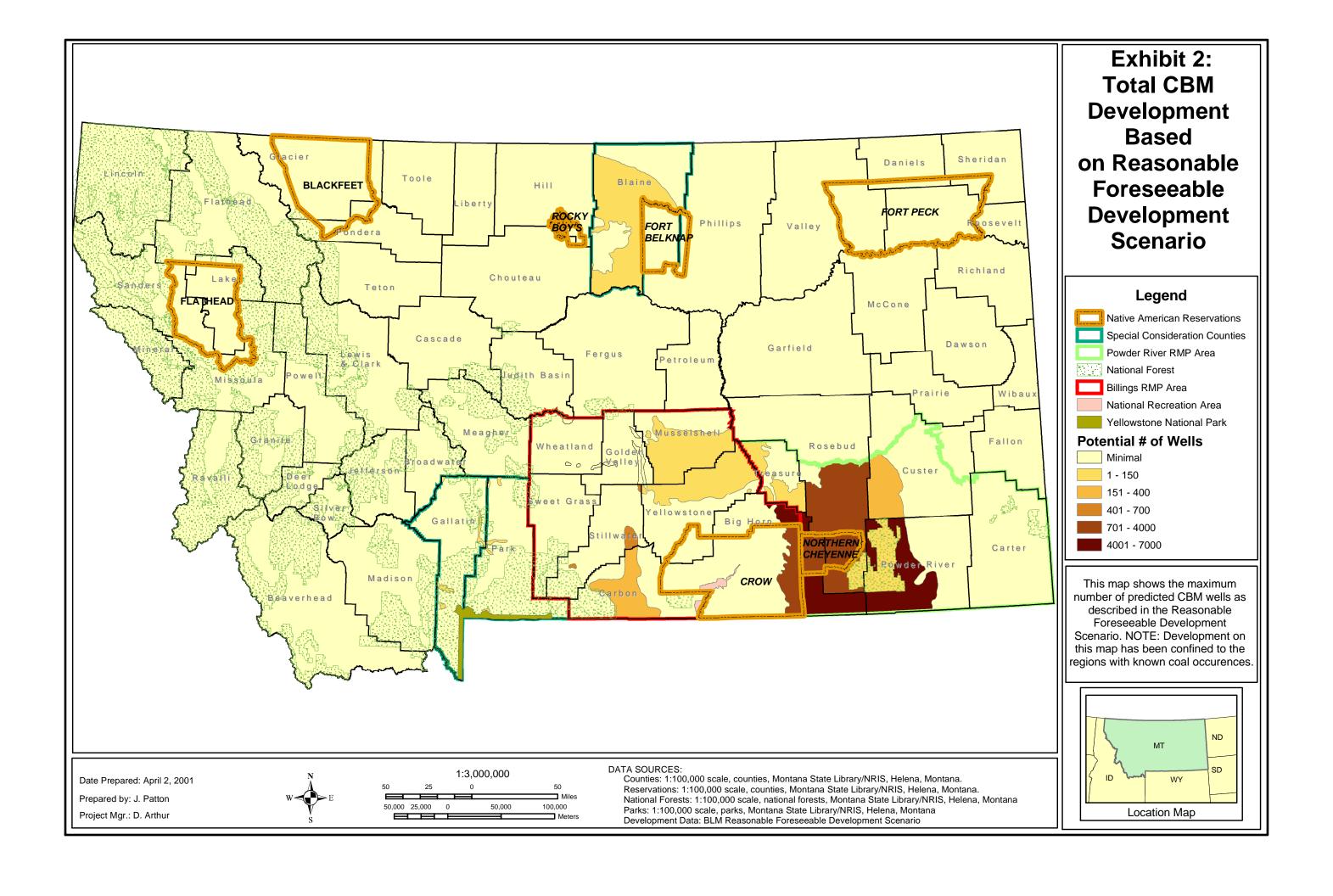
Historical drilling activity and oil and gas price projections were used to project conventional oil and gas development for the emphasis area (above). The RFD scenario describes a somewhat different level of activity than the scenario found in the BLM *Final Oil and Gas RMP/EIS Amendment* issued in 1992. This is primarily because of the use of a different span for historical drilling activity. The 1992 amendment used the span from 1973 to 1988 in forecasting future activity. The document used a total period of 80 years in forecasting future development. This led to a slight difference in the level of drilling activity forecast. Approximately 200 to 800 wells would be drilled in the Powder River RMP area. Approximately 250 to 975 wells would be drilled in the Billings RMP area. A total of 450 to 1,775 wells would be drilled in the next 20 years.

Exhibit 2 shows the total RFD for the CBM emphasis area, which includes the Montana portion of the PRB. Also shown on this exhibit are Native American Reservations, National Forests, National Parks, and National Recreation Areas. Review of this exhibit shows potential CBM development throughout the majority of the Montana PRB. Estimates are based on full-field development by county and shaded areas represent occurrences of sub-bituminous coals within the counties where development is likely to take place.

Analysis of the RFD with respect to the Montana portion of the PRB suggests that approximately 4,095,000 acres of the total 5,984,000 acres that make up the PRB are expected to have CBM development. The total RFD for this area (including federal, state, and private mineral ownership) amounts to approximately 24,875 total CBM wells. Exhibit 3 illustrates the maximum potential well development as described in the RFD by watershed, shaded for coal occurrences within the basin. This exhibit shows how the predicted CBM development from the RFD intersects watersheds in the PRB of Montana. The development scenario presented in this exhibit represents total drilled wells. It is expected that about 10 percent of these wells will be dry holes.

Exhibit 4 indicates the surface area of each watershed within the PRB overlying the known coal occurrences and the predicted number of maximum wells per watershed. This exhibit shows that the potential total area within each watershed that may be impacted by CBM development ranges from 24,000 acres (Mizpah watershed) to approximately 1.3 million acres (lower Tongue watershed). Similarly, CBM development ranges from high concentrations of approximately 5,809 and 5,397 in the upper Tongue and Rosebud watersheds, respectively to only 224 CBM wells in the Mizpah watershed. Consider the total RFD for the state, this exhibit shows that the vast majority of CBM development is expected to occur in the Montana portion of the PRB.





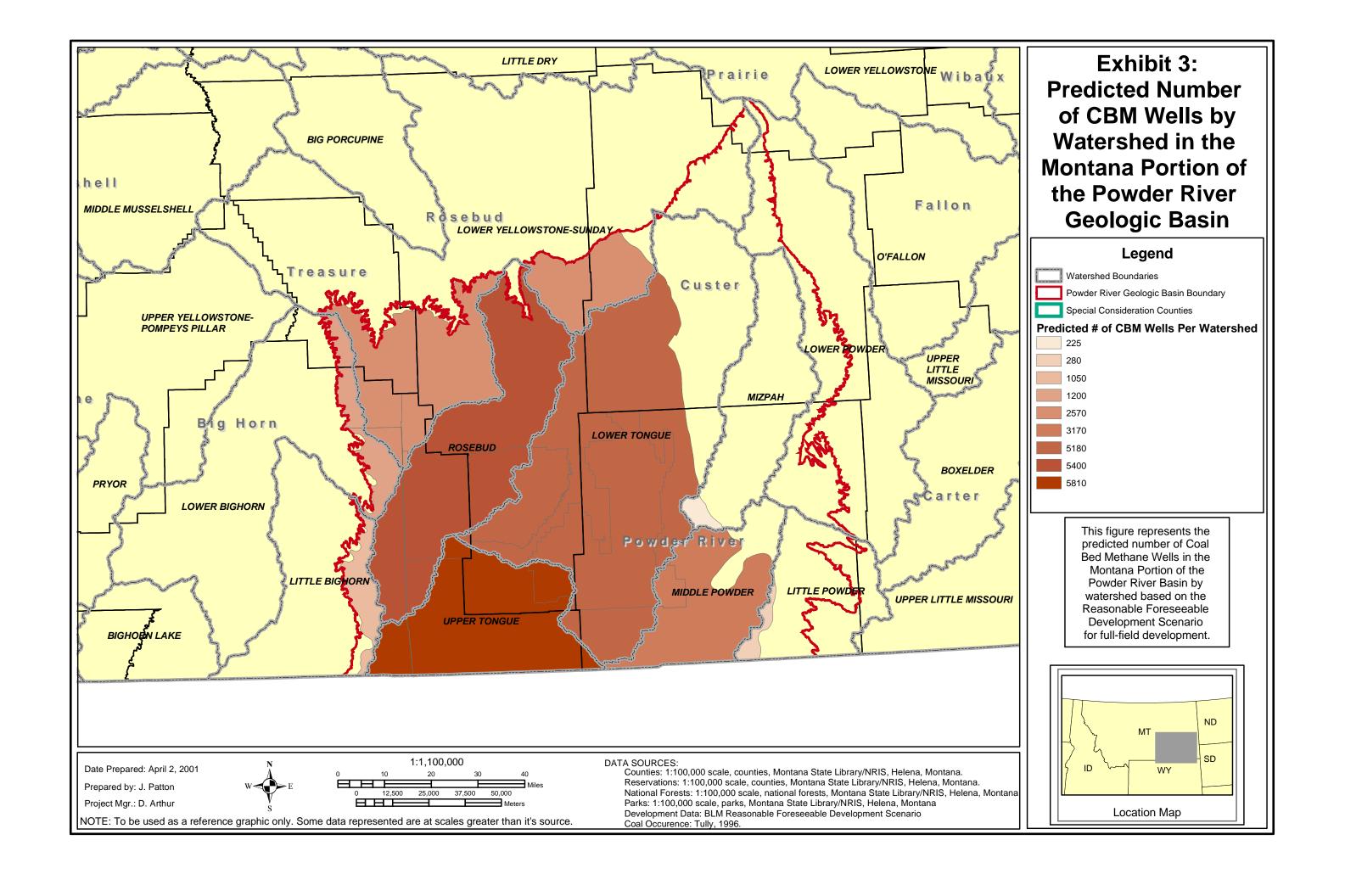


EXHIBIT 4 - WATERSHED ACREAGE AND MAXIMUM POTENTIAL CBM WELLS IN THE PRB

This table indicates the surface area of each watershed within the PRB overlying known coal occurrences and the predicted number of maximum potential wells per watershed.

WATERSHED	SURFACE ACREAGE OF IMPACTED WATERSHED	POTENTIAL WELLS DRILLED	
Little Bighorn	87,000	1,050	
Little Powder	29,500	278	
Lower Bighorn	121,500	1,200	
Lower Tongue	1,374,000	5,183	
Lower Yellowstone-Sunday	687,500	2,568	
Middle Powder	368,500	3,167	
Mizpah	24,000	224	
Rosebud	814,000	5,397	
Upper Tongue	589,000	5,806	
Total	4,095,000	24,875	

APPROACH AND METHODOLOGY

Hydrological resources in the PRB are vitally important to residents of this semiarid country. In a region that receives 16 inches or less of precipitation each year (NOAA 2001), residents want to understand the possible impacts of produced water derived from CBM. Each productive CBM well produces water from underground coal seams in quantities that can be quite large over the life of an individual well. Assuming an average life of perhaps 20 years, a single CBM well could produce as much as 105 million gallons of water². Considering a possible development scenario of approximately 26,000 CBM wells throughout the CBM emphasis area, the total volume of water produced from CBM wells in Montana could exceed 3 trillion gallons of groundwater³.

Because of the volume of water being considered, its origin, and quality, several issues that do not commonly cause significant concern with respect to conventional oil and gas development may pose potential significant threats with respect to CBM development. To better understand these issues, this technical report uses an approach that emphasizes known information so clarified understandings of the existing environment and impacts from CBM development can be achieved. Specific issues identified for review in the technical report are listed below with brief descriptions of each issue:

- **EXE** Hydrologic Setting and Framework: Significant study has been performed on the hydrologic settings and framework in the CBM emphasis area and the PRB. To facilitate the assessment of environmental consequences of CBM development, a thorough understanding of this framework is instrumental. Discussion of the hydrologic framework will include some statewide discussion, with emphasis on the PRB.
- **Hydrology Regime**: The extent of the groundwater resource will be included in a water balance discussion of present and future usage.
- **Coal Seam Reservoir Parameters and Regional Variations**: Throughout the CBM emphasis area and the PRB, underground coal seams vary substantially. Although fully defining the reservoir parameters and all regional variations are not possible or practical, the report presents general information regarding the characterization and heterogeneity of potential CBM producing coal seams that are likely to be primary targets for exploration and production activities.

² Average long-term production rates for CBM wells could be as much as 10 gallons per minute over the life of a typical well. Therefore, the total water volume for 20 years of active production would be approximately 105 million gallons (*Calculation: 12 gallons per minute x 60 minutes per hour x 24 hours per day x 365 days per year x 20 years*). However, based on declining water production rates, the anticipated averaged production rate for a CBM well is 2.5 gpm over a 20 year production period.

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Total produced water volumes for full-field development, including approximately 24,000 production wells, would amount to more than 3 trillion total gallons of water (*Calculation: 126 million gallons per well x 24,000 potential wells*).

- Faulting and Fracturing Relative to CBM Development: The entire CBM emphasis area is a complex geologic framework with areas that have prolific faulting and fracturing. The presence of faults and fractures in the CBM emphasis area (including the Powder River Basin) has raised concern regarding the potential influence these faults and fractures may have. This document discusses faults and fractures as barriers and storage features.
- Artificial Penetrations: Considering the relatively shallow depths to potentially productive coals in some parts of the CBM emphasis area, concerns regarding artificial penetrations have been raised through the public scoping process. Therefore, a discussion relative to artificial penetrations has been included in the Technical Report.
- **Groundwater and Surface Water Interaction**: Understanding hydrologic systems can provide insight toward evaluating potential impacts of a proposed action. Under CBM development, both groundwater and surface water impacts are discussed.
- **Groundwater Production and Usage by Aquifer and by Area**: To better understand groundwater issues relative to CBM development, a basic understanding of groundwater production and usage is necessary. Therefore, available information concerning production and usage is presented.
- Water Quality Characterization and Impacts: Possible water quality impacts from CBM development, including geographic distribution of potential impacts, are largely unknown. A general water quality characterization of both groundwater and surface water can be accomplished by analysis and review of existing data. Furthermore, insight into previous and ongoing analyses in this area is believed to be necessary for ultimate determination of environmental consequences.

In addressing the above technical issues, data will be acquired from a variety of sources, including the Montana Bureau of Mines and Geology (MBMG), Montana Department of Environmental Quality (MDEQ), Montana Board of Oil & Gas Conservation (MBOGC), United States Geological Survey (USGS), and the BLM. Other information and data sources will be used as determined necessary.

GROUNDWATER MODELING

Groundwater modeling is not being conducted as part of the technical analysis of this document. Results from various groundwater models performed as part of separate CBM studies have been considered. Environmental impacts from water production as a part of CBM activity can be predicted by modeling current conditions and expected development. Mathematical modeling calculates changes in hydraulic head because of withdrawal of water and measured reservoir parameters. Mathematical models require a certain level of knowledge of local conditions, including reservoir pressures, reservoir parameters such as porosity and permeability, and potential producing rates. Modeling can involve simple two-dimensional (2-D) calculations to quantify the potential radius of drawdown influence. If localized knowledge is sufficient, a 3-D model can be constructed that honors directional changes in reservoir parameters and complex interferences of multiple producing wells. Groundwater models that have been performed with respect to CBM production considered in this document are as follows:

- ?? The Buffalo, Wyoming, Field Office of the BLM contracted with a hydrology firm to produce a multi-layer 3-D model of the Wyoming portion of the PRB (BLM, 1999a). This model (VMODFLOW v.2.61) consisted of eight isotropic layers including coal and sand aquifers and various aquacludes. The modeling was intended to predict spatial and depth distributions of water level drawdown within several aquifers and to predict cross-flow between aquifers.
- ?? The Durango, Colorado, District Office of the BLM (BLM, 2000a) contracted a single-layer (VMODFLOW v. 2.8.2) model of the New Mexico and Colorado portions of the San Juan Basin (SJB), an area of intense CBM development. The modeling was designed to predict water level drawdown within the generalized coal aquifer.
- ?? Small-scale, two-dimensional models have been performed in the PRB (Williams, B. 2001; Pennaco 2000; Peacock et al, 1997). These models are single-layer expressions of fluid-flow equations assuming isotropy. The models are intended to predict water level drawdown in a single aquifer in terms of radius from extraction points or the center of a proposed well field.

Predictive modeling of groundwater in the Montana portion of the PRB is hampered by three data deficiencies, hydraulic parameters of the coal aquifers, anisotropy (directionality) of reservoir parameters, and geographic distribution of CBM development areas. Only one small area has been developed for CBM in the PRB emphasis

area—the CX Ranch represents an area of approximately 11 square miles. The CX Ranch contains nearly 200 producing wells that have yielded reservoir data such as porosity, permeability, hydraulic conductivity, and storage coefficients in the subsurface. The subsurface analyses from full-hole cores gives a good approximation of these important reservoir down-hole properties. On the other hand, analyses from outcropping surface coals (Davis 1984 and Montana Department of State Lands (MDSL) 1982) produce data that may or may not be close approximations of subsurface measurements (BLM 1999a). Exposure at the surface dries out the coal, accentuates cleat (natural fracturing) and apparent porosity, and changes the texture of shaley interbeds; this may significantly alter reservoir parameters (BLM 1999a). Additionally, multi-well pumping tests in the emphasis area are almost non-existent; multi-well testing is the best way to evaluate reservoir conditions beyond the dimensions of the single bore-hole (BLM 1999a). The lack of high quality reservoir parameters from subsurface samples and multi-well pumping is a definite hindrance to 3-D modeling.

The directionality of reservoir parameters, such as permeability and hydraulic conductivity, has not been examined throughout most of the Montana portion of the PRB (Davis 1984). Permeability and hydraulic conductivity are dependent on matrix porosity and fracture development. Fracturing may be due to regional scale tectonics such as those associated with the northeast southwest faulting around the CX Ranch area (Bergantino 1980), or may be due to flexing over structural noses and four-way closures in the area. In any given area, fracturing can be due to several causes and be extremely variable in direction and density. The effect of directionality may exceed 250 percent (Davis 1984).

Three-dimensional modeling can predict possible combined effects from closely spaced CBM developments. In the PRB, however, it is unknown where these future CBM fields might be located, or how many might be in place within the next 10 or 20 years. In particular, it is unknown whether the upper Tongue River Member coals will be the only economic CBM reservoirs or whether deeper coals may also be economic. Future economics will also determine the spacing and number of CBM fields throughout the Montana PRB.

Due to these complexities, the BLM and State made the determination to ask the MBMG to move forward with two (2) separate groundwater-modeling projects specifically tailored to the needs of the EIS. These models will include a two-dimensional single-layer model of the PRB to determine drawdown effects of potential CBM development and a 3-dimensional model of a hypothetical CBM project in the area of Hanging Woman Creek. Results of these models will serve a similar purpose as this technical report and will be used in support of the Montana CBM EIS.

CHAPTER 2 - COAL BED METHANE OPERATIONAL SUMMARY

CBM has been produced in the Powder River Basin of Montana since April 1999. The first exploration wells were drilled in 1990 in both the Big Horn and Powder River Basins. The bulk of the producing data has, however, less history than that. In the CX field, operated by Fidelity Exploration & Production Company, approximately 20 months of production data have been submitted to the MBOGC. The majority of CBM production is from the D-3 coal at approximately 250 to 300 feet deep. Additional CBM production is achieved from the Monarch coal at a depth of approximately 400 feet and the Carney coal at a depth of approximately 600 feet. In the CX field, these coals maintain sufficient separation that pressure communication is likely not significant. No well is completed in more than one coal (Williams 2001).

WELL DRILLING AND COMPLETION

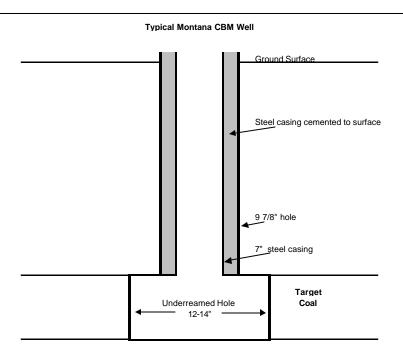
The drilling of a CBM well in the Montana portion of the PRB has commonly been done in three distinct stages. First, if necessary to protect vulnerable alluvial aquifers at the surface, a small truck-mounted drilling rig referred to as a Spudder rig is used to start the drilling process and set an appropriate amount of conductor pipe to protect shallow alluvial aquifers. In the Montana PRB, alluvium is usually less than 90 feet thick where present, and most CBM wells in Montana are not completed with this shallow protective casing due to the absence of an alluvial aquifer. Next, a larger drill rig is brought to the well site to facilitate drilling to the top of the target coal seam. Once drilling is completed and the target coal seam is reached, a steel production casing is placed in the well and cemented in-place from the bottom of the drilled hole to the surface using standard oilfield cement. At the CX Ranch Field, three coal seams have being targeted for CBM production and each well has been completed in one of these seams. To date, other coal seams present have either remained undrilled or have been cased off. After the cement used to set the production casing has cured, a third completion rig is often used to drill out the cement plug left at the bottom portion of the drilled hole. This drill rig is also used to drill a pilot-hole to the base of the target coal, and under-ream the coal section. The producing section is left open for production purposes.

Exhibit 5 is a schematic view of a typical CBM well from the CX Ranch. This exhibit shows the more common well completion scenario where conductor casing is not used. Although there are variations in this drilling and completion methodology, the approach is generally common for current practices. However, future practices could vary from this method depending on the depth of targeted coal seams advances in drilling technologies, or changes in drilling philosophies. Potential changes could include, but may not be limited to, completing wells in more than one coal seam or drilling directional or horizontal wells.

To date, drilling has been done with fresh water drilling fluids to protect the aquifers and the coals being drilled. Water supply during the drilling phases is most often from produced water, although ponds can also be utilized. The bore-hole will finally be cleaned with a slug of formation water pumped at a high rate to flush the coalface. The wells are not artificially fractured during completion activity, although this technique may be used in other parts of the PRB or in other areas of Montana where natural fracturing (cleat) may not be developed. An electric submersible pump (ESP) is installed near the base of the coal on the end of fiberglass tubing. To help monitor the water level in the well, a 1/4-inch capillary tube may be installed for data collection purposes.

EXHIBIT 5 - TYPICAL CBM WELL IN THE MONTANA PORTION OF THE PRB

This exhibit diagrams a CBM well as they are typically drilled in the CX Ranch Field. In addition to the elements shown, there may be local variations.



CBM PRODUCTION OPERATIONS

During production, water is pumped up a tubing string to be filtered, metered, and put into a water flow-line for handling or discharge. At the only producing CBM field in the Montana portion of the PRB, the water is either used in drilling new wells, pumped into ponds for use by the land owner, or discharged to the Tongue River through a MDEQ discharge permit. Although many additional water use and disposal methods have been suggested and could be used if CBM development continues to increase, current water handling practices are limited.

Immediately after the well is drilled, the water level stands at some elevation above the level of the coalbed, an expression of the virgin reservoir pressure. At this pressure, methane will not flow into the wellbore (Williams 2001). After initial pumping, the water level is reduced, allowing methane to flow out of the coal seam into the borehole up to the surface. The gas comes up the casing-tubing annulus and runs into a low-pressure (approximately 5 pounds per square inch [psi]) flowline. The natural gas consists of approximately 96 percent methane, 3.5 percent nitrogen, and trace amounts of carbon dioxide (CO₂). The flow-line connects to a metering manifold that knocks out the last of the water and connects to an approximately 400-horsepower (hp) field compressor that increases pressure to approximately 40 psi in a gathering pipeline. The gathering lines are connected to a large sales compressor station that builds pressure to approximately 1,000 psi in the regional sales pipeline. All CX Ranch producing wells are currently equipped with individual totalizing wedge-meters rather than estimated from grouped well rates. When the field began producing, some well production volumes were estimated. Since the field's inception, meters have occasionally become plugged. In those instances, production volumes have been estimated.

Produced water is piped away from the wellsite and managed in several ways. Currently, the majority of the produced water is discharged to the Tongue River under the authorization of a Montana Pollutant Discharge Elimination System (MPDES) permit issued by the MDEQ. The MPDES Permit (No. MT-0030457 as modified on July 3, 2000) is effective until March 31, 2002. As modified, the permit allows discharge flow up to 1600 gpm into the Tongue River via any combination of 11 specific discharge points. The discharge flow limit is based upon gauging statistics from 1960 to 1994 and specifically is based upon a 7-day average low-flow rate expected every

ten years. If the field is discharging at its maximum rate and the river is at its 10-year low-flow rate, the resulting dilution factor will be approximately 12:1. The permit requires that the filtered, produced water be delivered to the discharge point by pipeline rather than a ditch, so that suspended sediment is not incorporated and does not impact the river.

Part of the produced water is currently delivered to several ponds constructed on the fee land leased by Fidelity Exploration & Production Company. These ponds are unlined and supply water to livestock as well as wildlife in the area.

CBM wells must pump water from the reservoir to lower pressure within the coal, to augment the formation of cleat, and to allow the natural gas to break out as a discrete phase. The amount of water that must be pumped off appears to vary not only from reservoir to reservoir, but also during the history of each individual producing well according to the specific coalbed reservoir it is producing from, and its proximity to other producing wells. Exhibit 6 presents a list of the average water production rates for approximately 200 wells in the CX field normalized to the age of each well (MBOGC oil and gas database). This data was compiled by averaging the water production rates from active CBM wells from the date of first production. For example, the average for month zero was determined by averaging the water production from all wells reporting for the first time that month, regardless of the calendar date production was initiated. A similar approach was used for each consecutive month. Results from this analysis show that water production rates declined steadily at the CX Field from approximately 12 gpm to slightly less than 8 gpm over a period of 20 months.

EXHIBIT 6 - AVERAGE PRODUCTION RATES IN THE CX FIELD, NORMALIZED TO AGE OF EACH WELL

Historical water production rates in the 200 CBM wells in the CX Field, Montana (MBOGC, April 2001).

AGE IN MONTHS SINCE FIRST PRODUCTION	AVERAGE WATER PRODUCTION (BWPD)	AVERAGE WATER PRODUCTION (GPM)
0	418	12.2
1	428	12.5
2	398	11.6
3	553	16.1
4	556	16.2
5	503	14.7
6	460	13.4
7	398	11.6
8	412	12.0
9	394	11.5
10	411	12.0
11	427	12.4
12	419	12.2
13	375	10.9
14	376	11.0
15	303	8.8
16	305	8.9
17	430	12.5
18	367	10.7
19	253 7.4	
20	267	7.8

(Notes: gpm = gallons per minute, barrel = 42 gallons, BWPD = barrels of water per day)

The data provided in Exhibit 6 was used to perform a water production decline analysis. Appendix A contains a series of three (3) graphs along with data used to create each graph and to perform the subject analysis. The first graph developed utilizes the normalized average CBM water production rates from Exhibit 6. This graph also shows a superimposed exponential trend-line for the raw production data. The second graph shows the exponential decline rate projected forward for a period of 20 years following the initial CBM production. The third and final graph combines the water production data and decline analysis to show a semi-log plot of normalized average CBM water production rates combined with the long-term exponential decline of the data analyzed. The projected average water production rate over a 20-year period as determined from the exponential decline analysis is approximately 2.5 gpm. The actual average water production rates for individual CBM wells may vary from this average based on location, coal seam thickness, well completion type, coal reservoir properties, and other factors. This projected average production value represents a more realistic rate calculated from historical decline rates in CBM water production.

CHAPTER 3 - GEOLOGY AND HYDROLOGY

INTRODUCTION

Montana is the site of the juxtaposition of the Great Plains with the Rocky Mountains. The rocks at the surface vary from the ancient metamorphic and igneous complexes forming the cores of some mountains to Recent sediments in the major river valleys of the state. Geology of Montana plays an indispensable role in forming the mineral resources, visual resources, and water resources of the state. The geologic history of the state has been a series of major structural events in the tectonics, or continent building of North America.

Exhibit 7 is the Tectonic Element Map of the State of Montana. The map shows the locations of important basins such as the Big Horn and Williston that have trapped sediment containing coal, oil, and natural gas. The map also locates mountain ranges such as the Crazy Mountains and Black Hills that served as sources for some of the sedimentary units. Several tectonic elements will be discussed in detail throughout this Technical Report including those features that affect the state's resources – The Powder River Basin, The Big Horn Basin, Big Horn Mountains, the Bull Mountains Basin, and others. These major tectonic elements control the porous reservoirs that hold the usable water, oil, and natural gas. They also control the impermeable barriers to fluid movement. These elements also control the local folds and faults that form the oil and gas fields of the state.

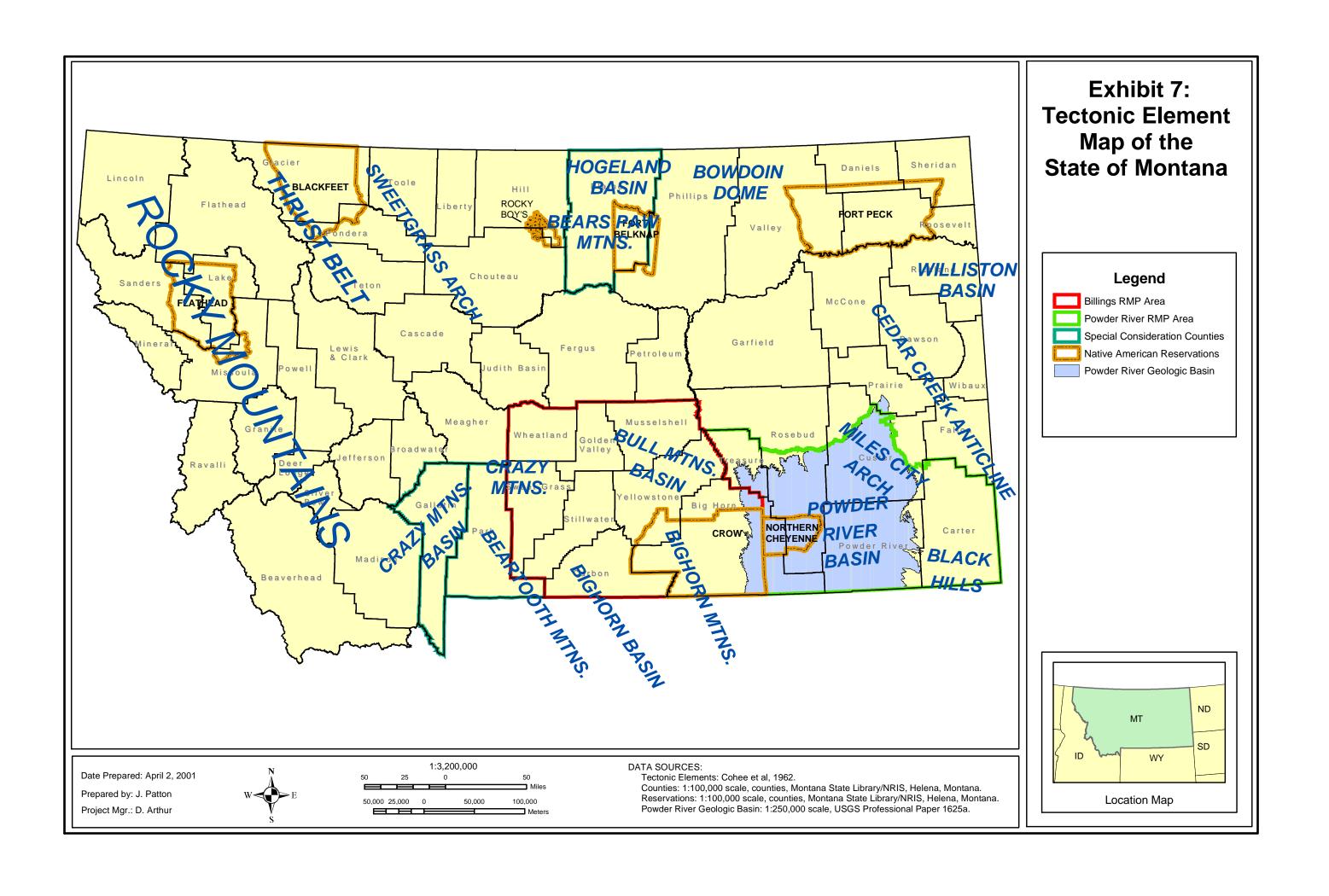
Montana's basins have accumulated sediments several miles in thickness; these sands, shales, and limestones form the source and reservoirs of Montana's fossil energy reserves – crude oil, natural gas, coal, and coal bed methane (CBM). In these basins, ancient sediments were buried to great depths within the earth where heating and increased pressure formed the fuels from the raw plant materials trapped in the sediments. The sedimentary basins also hold a significant portion of the water resources of the state; in the deep parts of these basins the water is generally salty while the shallower parts of these basins there is fresh water of meteoric origin.

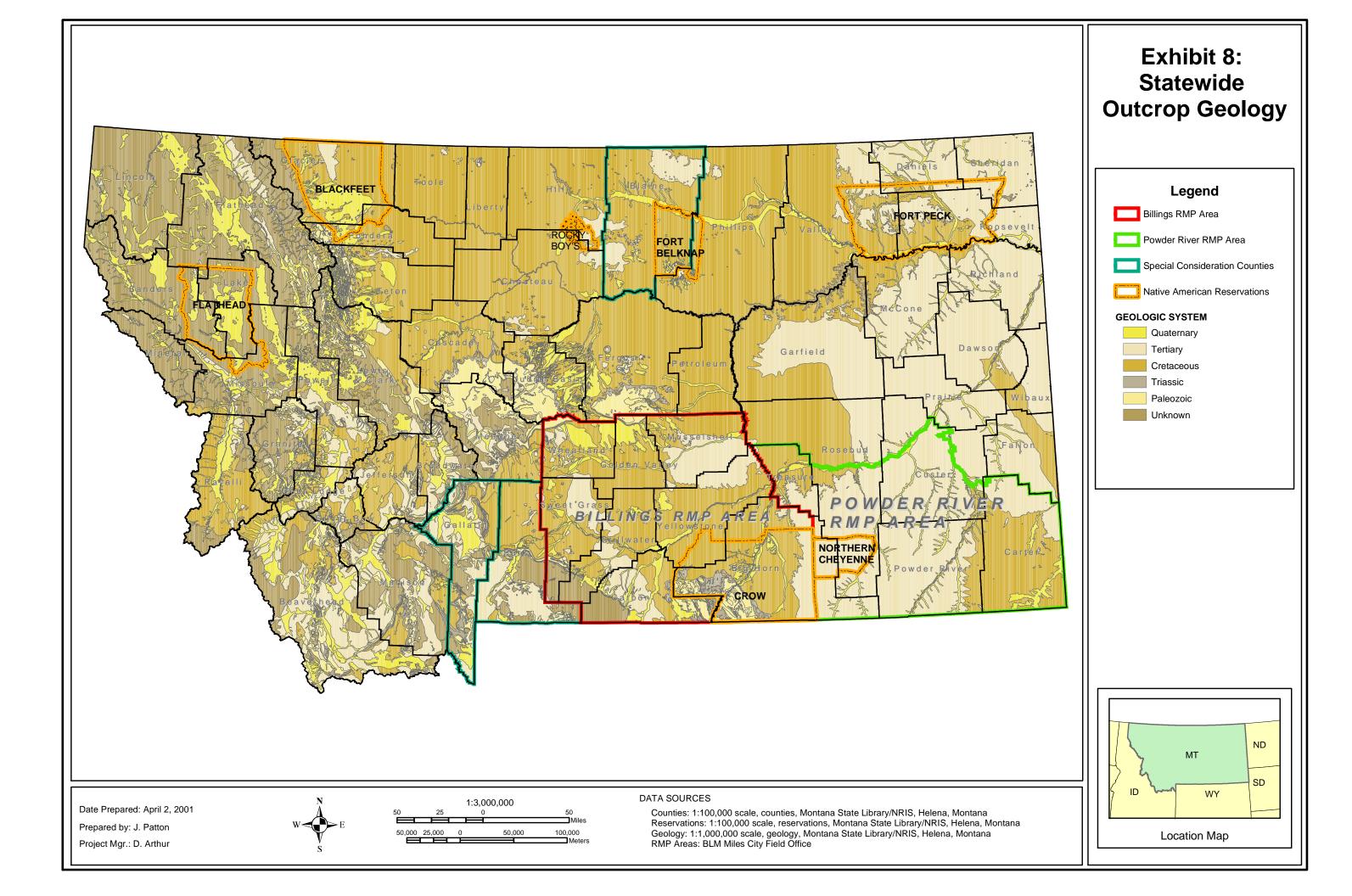
Exhibit 8 presents a map of the statewide outcrop geology. The map emphasizes broad basin features underlying the Great Plains in contrast to the intensely contorted structures under the many mountain areas. The basins mentioned above as likely to contain CBM resources, such as the PRB, can be seen as broad expanses of similar outcrop. In the case of the PRB, rocks at the surface are all coal-bearing Tertiary formations except for the scattered Quaternary age Alluvium in stream and river valleys. Other basins contain coal-bearing sediments of Cretaceous age. The presence of large volumes of suitable coal is vital for predicting CBM development.

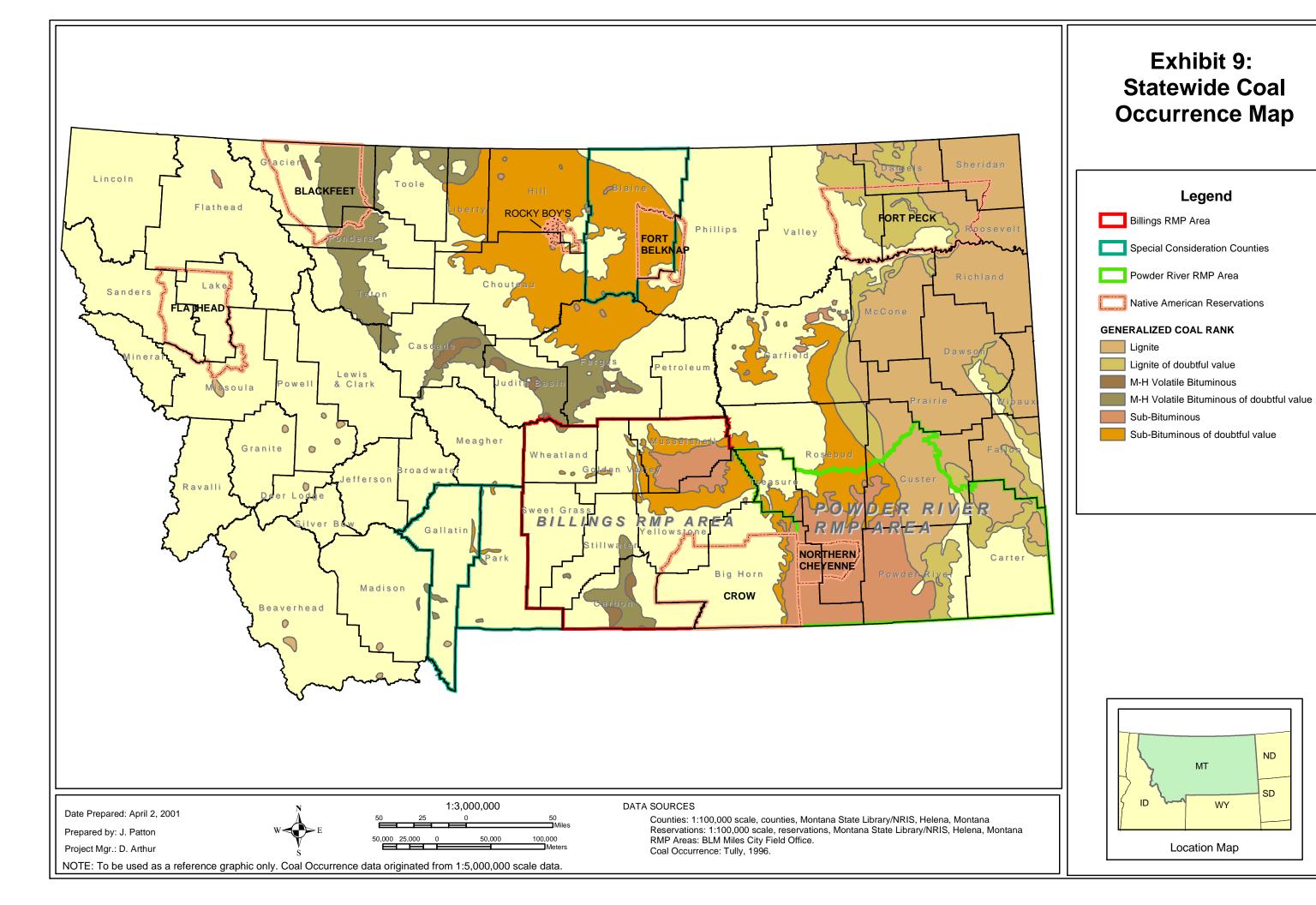
CBM is the focus of this EIS; its exploration and production is discussed in Chapter 2 and it is important to recognize that the resource is intimately associated with coal deposits. The methane gas is generated by the coal deposit both under thermogenic (heat-driven) and biogenic (microbe-driven) conditions. At the same time, the methane is trapped in the coal seams by the pressure of groundwater. Releasing the pressure of groundwater from the coal aquifers liberates methane, allowing it to be produced and sold. The magnitude of the CBM resource is determined by coal type and volume; the location of coal reserves will predict the location of Montana's CBM resources.

Exhibit 9 is the statewide coal occurrence map. The map displays the extent of coal deposits that support mines and are expected to support projected CBM development. The geology of Montana has given rise to several different kinds of coal; the most important differentiator is coal rank or thermal maturity. As coal is buried or otherwise heated, the raw plant material is gradually converted from complex carbon compounds to simple compounds and elemental carbon. Exhibit 9 highlights coal rank or maturation ranging from lignite, sub-bituminous, high-volatile bituminous, medium-volatile bituminous, low-volatile bituminous, and anthracite coals (Leythaeuser and Welte, 1969). The areas of interest are the PRB, Bull Mountain Basin, and Blaine County, which contain mostly sub-bituminous coal that has not reached a high degree of maturation. Also of interest for CBM are the Big Horn Basin and the counties of Park and Gallatin that contain medium and high volatile bituminous coal of slightly higher maturity.

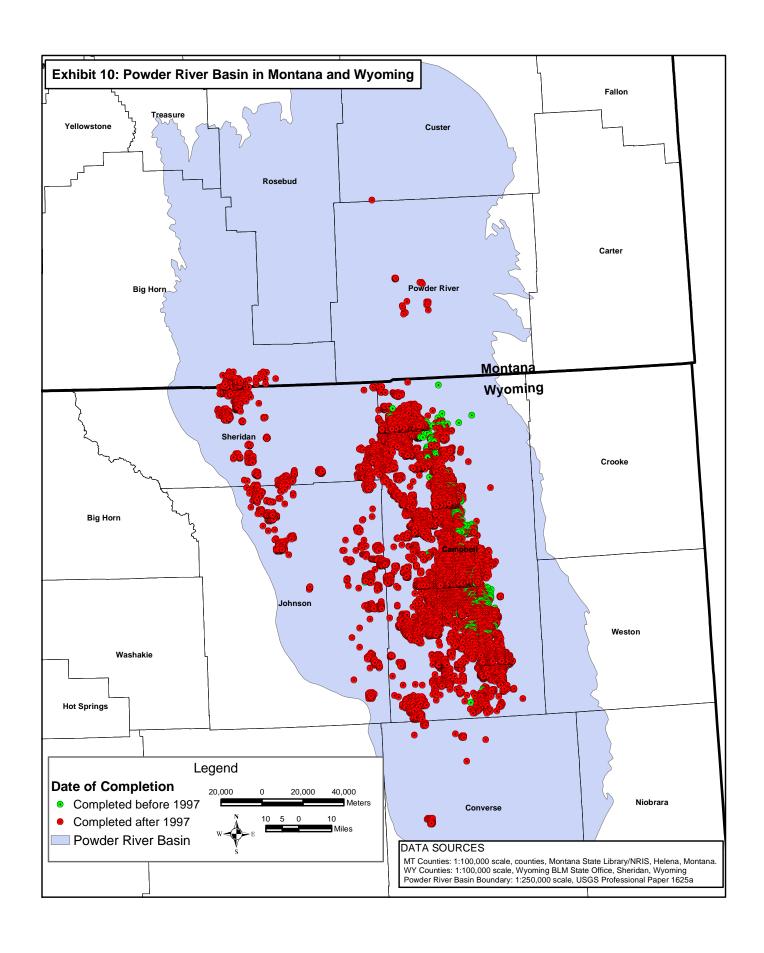
Exhibit 10 shows the cereal extent of the PRB throughout Montana and Wyoming as current CBM development. Analysis of this exhibit shows that over half of the basin is located in Wyoming. The exhibit emphasizes the increase in drilling throughout the entire basin after 1997. The map also highlights he lack of drilling in the Montana portion of the PRB.







ND



According to the Montana Board of Oil and Gas Conservation (MBOGC) records, CBM has been produced only in the CX Ranch field in the Montana portion of the PRB since April 1999. Exploration solely for CBM first happened in the Montana PRB in December 1990 in the area of CX Ranch. However, the first CBM exploration in the state was in August 1990 in the Big Horn Basin where CBM was tested but never sold. In many parts of the state, coals are aquifers that contain significant amounts of groundwater and are used by residents for water needs. In order to produce the methane in the Montana part of the PRB, groundwater must be drawnoff the coal aquifer. Unless groundwater is produced from the coals, methane will not be produced; water production cannot be avoided during CBM development. This is the central conflict between CBM and traditional uses of the land; when CBM is produced, local coal aquifers are partially depleted. Depending on the area, this depletion may extend beyond the CBM producing field boundaries.

REGIONAL GEOLOGY

The planning area of the EIS centers on the Powder River RMP area and the Billings RMP area. The planning area contains three major basinal features – Powder River, Big Horn, and Bull Mountains – and surrounding uplifted areas. All three basins were formerly broad shelf areas until Laramide tectonics caused uplift in the surrounding features and this uplift contributed to sedimentary subsidence within the basins during the Late Cretaceous and Early Tertiary. The Bull Mountains Basin and PRB were one continuous basin during the depositional periods of the Cretaceous and Early Tertiary. It was post-depositional tectonics that divided the two (Stricker, 1999). The asymmetric basins are the result of a combination of sedimentary and structural subsidence with most of the fill consisting of the Fort Union Formation. The Fort Union Formation also contains most of the coals occurring in these three basins.

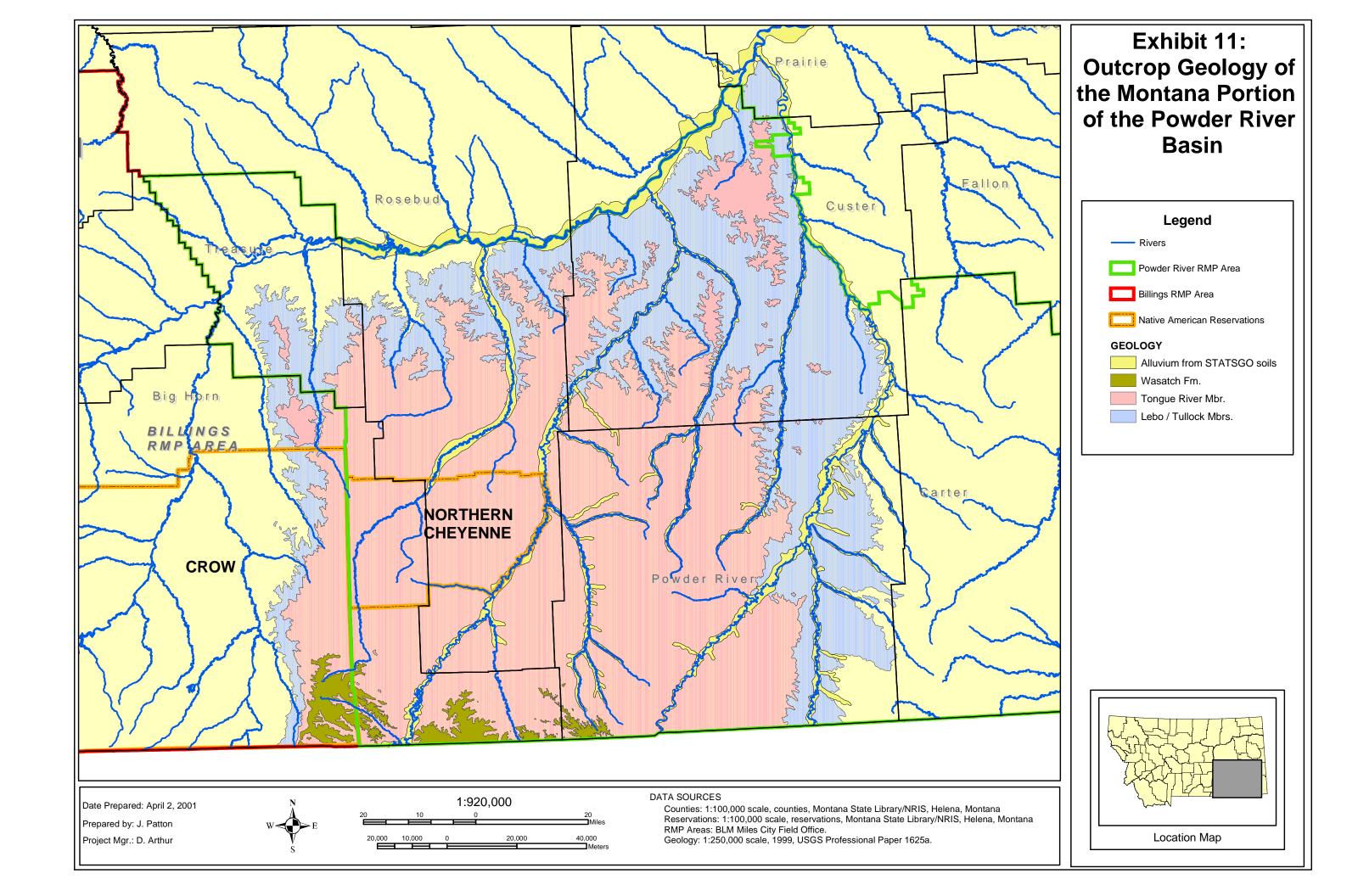
The PRB in its entirety covers approximately 12,000 square miles with the smaller portion in Montana (Ellis et al. 1998). The PRB is bounded to the west by the Bighorn Uplift, to the southwest and south by the Casper Arch, Laramie Mountains, and Hartville Uplift; and to the east by the Black Hills Uplift. The Miles City Arch and the Cedar Creek Anticline to the north essentially separate the PRB from the Williston Basin. Coal has been mined in the PRB since 1865 and large-scale strip-mining has been underway since the mid-1960s when demand increased for relatively clean-burning coals (Flores and Bader 1999). Conventional oil and gas have been exploited in the PRB for more than 50 years while CBM has been only lately developed with major activity beginning in 1997 (Rice et al. 2000).

Exhibit 11 depicts the outcrop geology of the Montana portion of the PRB. The map illustrates the broad geometry of the basin with the youngest Tertiary strata (Wasatch Formation) preserved in the deepest part of the basin just north of the Wyoming-Montana state line. The broad bands of the Tongue River and Lebo/Tullock members throughout most of the basin attest to the shallow dips to the east and north edges of the basin. The narrow outcrop bands on the west limb of the basin indicate that the basin is somewhat asymmetrical with steeper dips on the western side. Exhibit 11 also illustrates the scattered distribution of the Alluvium that fills the valleys of the basin.

Exhibit 12 portrays the distribution of water wells, the prospective CBM areas, and existing CBM production within the Montana portion of the PRB. The map was constructed from information in the MBMG Map 60 (Van Voast and Thale, 2001) and emphasizes those areas with thick, sub-bituminous and bituminous coal reserves. Coals are both water reservoirs and gas reservoirs and as such CBM production will affect local aquifers and even surface water. CBM development is expected to be concentrated in the southern portion of the PR RMP area although coals exist over most of the basin and CBM coverage could prove to be greater. The water wells shown in the exhibit could be at risk to drawdown impact from CBM development, especially those water wells completed in coal aquifers. Those aquifers at risk to CBM impact are described in the Hydrology section below.

STRATIGRAPHY

The stratigraphy of the planning area analyzes the age, composition, and continuity of sedimentary rocks. The sedimentary strata of the planning area extend backward in time from recent age alluvium found in stream valleys, to strata at the surface that is largely Tertiary and Cretaceous. These older sediments correspond to the Laramide tectonism that gave rise to most of the uplifted areas in Montana. Though the area contains significant regional thicknesses of older stratigraphic units, the Tertiary basin fills are of particular interest for coal, CBM, and groundwater production (Ellis et al. 1998). Conventional oil and natural gas occur in the older, pre-Laramide section but coals in the PRB are confined to the Early Tertiary units.



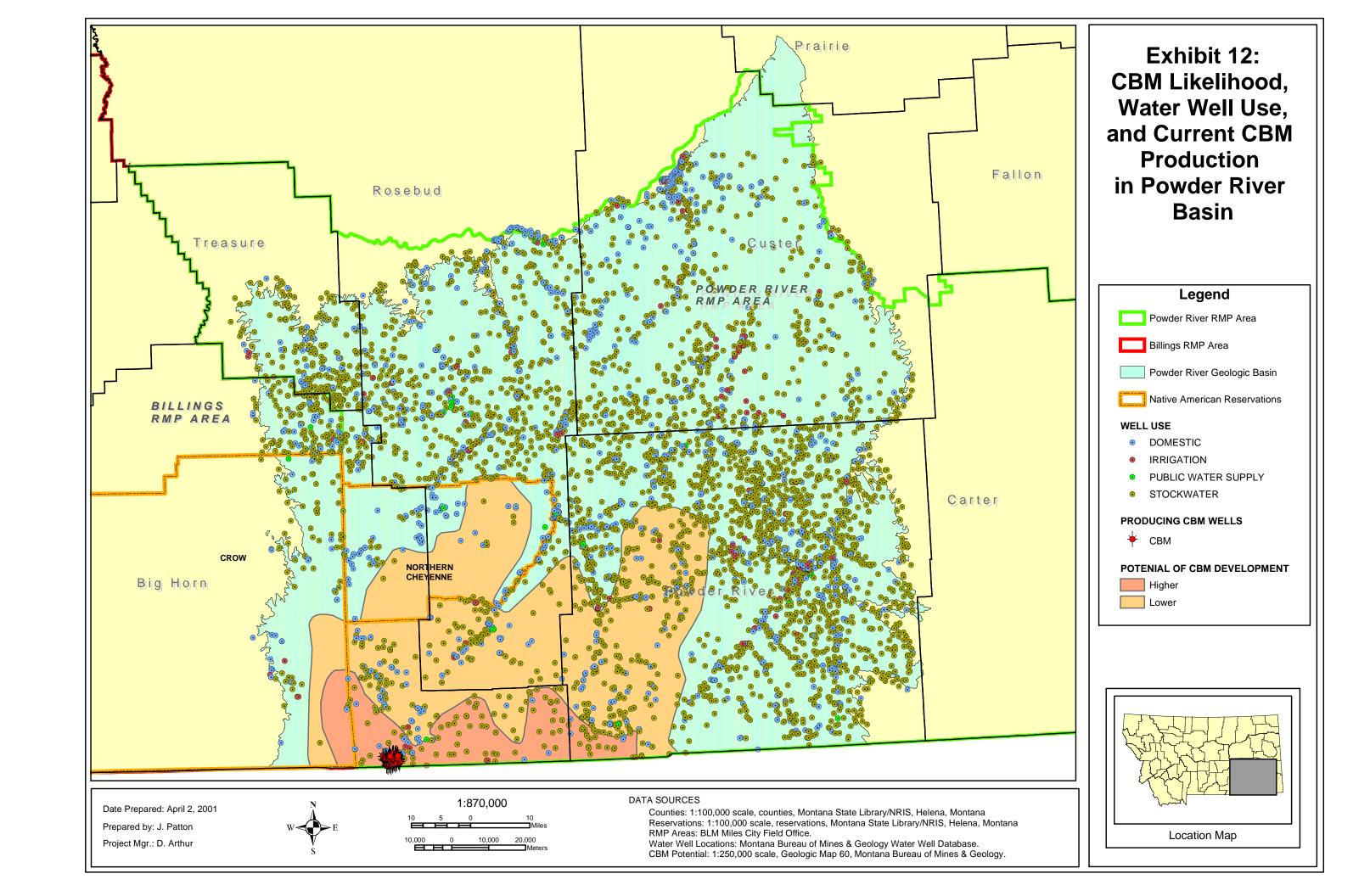
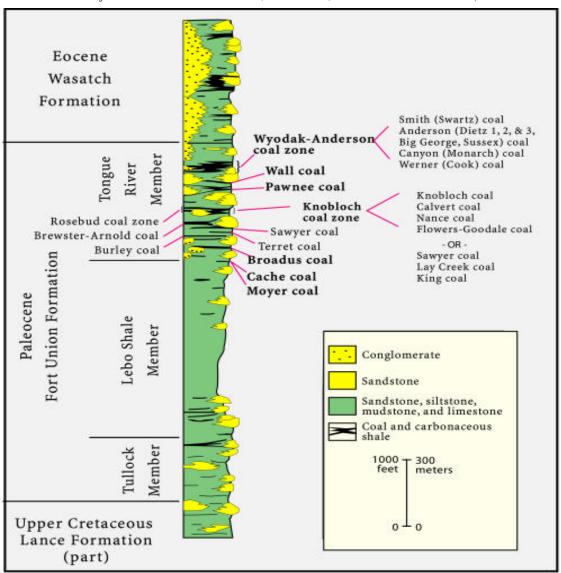


Exhibit 13 is a stratigraphic column of Upper Cretaceous and Lower Tertiary sediments in the Montana PRB. The stratigraphic column shows the continuous development of several thousand feet of sediments that include widespread sands, coals and fluvial, fine-grained sediments. The major formations are named along with major coal seams that are discussed in greater detail throughout the report. The basin's surface consists largely of the several members of the Paleocene Fort Union Formation, as well as the overlying Wasatch Formation in a small corner of the basin (Rice et al. 2000).

The Fort Union Formation encloses the various coal seams within the Montana portion of the PRB; these coals function as the source of the CBM, as well as aquifers carrying groundwater of varying quantity and quality. In the PRB coals range in depth from the surface to approximately 900 feet deep. Coals vary in thickness from over 50 feet and can form aggregate thicknesses over 100 feet. Coal seams in the Fort Union do not have significant matrix porosity and permeability (Gray 1987); they can act as aquifers because fluids such as water and methane are contained within the coal's fracture system, known as cleat (Montgomery et al. 2001). The fractures accumulate the fluids and allow the fluids to move horizontally and vertically.

EXHIBIT 13 - STRATIGRAPHIC COLUMN OF UPPER CRETACEOUS AND LOWER TERTIARY SEDIMENTS IN THE POWDER RIVER BASIN

Bedrock units that fill the PRB include the Lance, Fort Union, and Wasatch Formations (Rice et al. 2000).



Deep Formations

A number of regional stratigraphic units occur beneath the major basin fill units within the PRB. These formations are broadly present across Montana including the PRB. Penetrations of these formations by conventional oil and gas wells have been few and hydrocarbon production is scattered. The Cretaceous age Judith River, Shannon, Eagle, and Dakota/Lakota Formations are present in the subsurface between approximately 2,200 feet below ground surface (bgs) and 9,000 feet bgs. These four sandy formations are encased and overlain by thick Cretaceous shales of the Colorado and Pierre Formations (Noble et al, 1982). Reservoir quality sands are not present everywhere within each of these formations but each could locally be a suitable disposal zone for produced CBM water. In addition, the shales of the Colorado and Pierre Formations could perhaps accept produced water under injection pressures higher than fracture pressure. Only the Shannon Formation produces gas within the PRB.

The Upper Cretaceous Eagle Formation carries coals in Blaine, Park, and Gallatin counties (Nobel et al. 1982). These coals are prospective for CBM resources but currently do not produce.

Upper Cretaceous Lance Formation (Locally Represented by the Hell Creek Formation and Fox Hills Formation)

The Hell Creek and Fox Hills sands are Late Cretaceous in age and underlay the Fort Union in the Montana Portion of the PRB. They are the sand equivalents of the predominantly shaley Lance Formation. The sands are difficult to separate in outcrop, very difficult to separate in the subsurface, and appear to be in hydrologic continuity. Together, the Hell Creek and Fox Hills total approximately 500 feet of non-marine coastal plain sediments that have been shed from the mountains to the east and west (Perry, 1962). They are made up of variable, shaley sands that contain some of the youngest dinosaur fossils in the world. The sands are scattered over most of Eastern Montana but are not present everywhere in the PRB; the sands outcrop at the edges of the basin and are found as deep as 3,700 feet bgs near the axis of the basin in Montana (Miller 1981). The Fox Hills Formation lies conformably upon approximately 2,000 feet of Upper Cretaceous Pierre Shale. The Hell Creek is overlain by the thick Tertiary Fort Union Formation.

Paleocene Fort Union Formation

The Fort Union forms most of the sedimentary fill within the Montana PRB. It consists of approximately 3,500 feet of non-marine silty and shaley clastics and coal beds whose individual thicknesses can be as much as 37 feet near the Decker mine (Roberts et al, 1999a). The Fort Union also contains clinker deposits, formed by the natural burning of coal beds and the resultant baking or fusing of clayey strata overlying the burning coal, which are present throughout much of the area and can be more than 125 feet thick (Tudor, 1975). Stratigraphically the clinker bodies are part of the Fort Union but the clinker is a lithological unit composed of baked and fused siltstone, clay, and sandstone units that have undergone diagenetic changes during the combustion of the coal within the past 3.0 million years (Heffern et al, 1993).

Individual units within the Fort Union that were formed as fluvial deposits could be expected to have lithological flow-units oriented in a dip-wise fashion. This preferred direction of porosity and permeability could be exhibited by directional variations in groundwater drawdown levels. The coals, however, appear to have been deposited in mires situated above or below drainage levels within erosional channel features or perched above these channels in raised bogs (Ellis, 1998). Some of the coals, therefore, could exhibit linear permeability phenomena while other accumulations may be isolated lenses unconnected with other coal seams. In developing CBM fields, it will be valuable to identify these different coal bodies, but such research is beyond the scope of this report.

The Fort Union is split into three stratigraphic members: the lowest being the Tullock Member, overlain by the Lebo Shale Member, overlain by the Tongue River Member (McLellan et al. 1990). In the Montana portion of the PRB, the bulk of the coals are confined to the Tongue River Member, while the Lebo and Tullock Members are predominantly shale and shaley sand (McLellan et al. 1990). The Members are discussed in detail below:

THE TULLOCK MEMBER:

This is the stratigraphically lowest part of the Fort Union, consisting of approximately 300 feet to more than 500 feet of interbedded sands and shales with minor coals near the base (Tudor 1975). The Tullock rests unconformably upon the Upper Cretaceous Hell Creek Formation throughout the PRB. While generally sandier, the Tullock is difficult to separate in outcrop and in the subsurface from the overlying Lebo Member.

THE LEBO MEMBER:

This middle member ranges from 75 feet to more than 200 feet of claystones, limestones, and mudstones with the Big Dirty coal (3 to 13 feet of thickness) at the very base (Tudor 1975). The Lebo is, in part, stratigraphically equivalent with the overlying Tongue River (McLellan 1990).

THE TONGUE RIVER MEMBER:

The thickness of the Tongue River varies from 750 feet at the outcrop edge near the fringe of the basin to 3,000 feet near the axis of the basin (Williams 2001). Total coal isopach ranges up to approximately 150 feet (Ellis et al. 1999). The Tongue River Member is divided into three units. The lower unit includes that portion below the Sawyer coal seam. The Middle unit includes the Sawyer through the Wall coal seam. The Upper unit includes that portion above the Wall coal seam (Ellis et al. 1999).

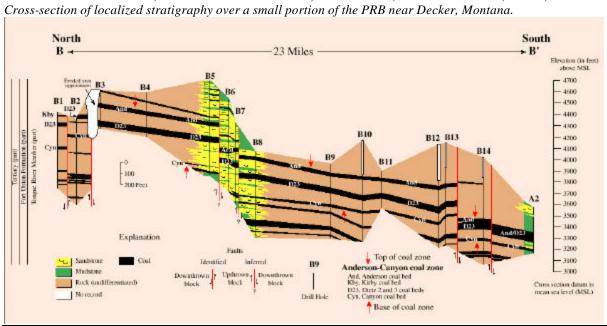
The Lower Tongue River unit is present across most of the Montana portion of the basin. It includes, from the base up, the Stag, Terret, Witham, Robinson, Rosebud-McKay, Flowers-Goodale, Nance, Calvert, and Knoblach coals. In the Ashland coalfield, the Lower Tongue River unit is up to 1,660 feet in thickness, and individual coals can be up to 71 feet thick (Roberts et al. 1999b).

The Middle Tongue River unit is present over a large part of the Montana portion of the PRB. It includes, from the base up, the Sawyer, Mackin-Walker, Cache, Odell, Brewster-Arnold, Pawnee, and Wall coals.

The Upper Tongue River unit is present only in the southern part of the Montana portion of the PRB. It includes, from the base up, the Otter, Cook, Carney, Canyon, Dietz, Anderson, and Smith coals. At the Decker mine, the Upper Tongue River is up to 1,500 feet thick; coals can attain an individual thickness of 57 feet and an aggregate thickness up to 111 feet (Roberts 1999a).

Although coals are the most economically significant part of the Tongue River Member, they form a small portion of the sedimentary volume. They are also extremely variable stratigraphically, as shown in the cross-section depicted in Exhibit 14. Exhibit 14 shows stratigraphic variation of the Anderson-Canyon Coals in the area of the Decker Mine, Powder River Basin, Montana.

EXHIBIT 14 - STRATIGRAPHIC VARIATION OF THE ANDERSON-CANYON COALS IN THE AREA OF THE DECKER MINE, POWDER RIVER BASIN, MONTANA (ROBERTS ET AL, 1999A)



Note: this cross-section reflects localized stratigraphy over a small portion of the Powder River Basin and is not intended to be a regional reflection of the entire Montana portion of the basin.

The cross-section illustrates the continuity or lack of continuity within the stratigraphic units. Coal aquifers can be seen to have local continuity but lack regional continuity. A local coal seam such as Dietz 1 can persist for several miles but the entire Anderson-Dietz package is eroded from the Colstrip area. The stratigraphic complications documented in Exhibit 14 suggest that even thinly separated coal seams may be very dissimilar. The cross-section illustrates the pinch-outs of coal seams, bifurcating coal seams, and erosional cut-off of coal seams by Paleocene and recent stream erosion. All of these factors can play a role in complicating the production of water and methane from the Fort Union Formation.

Fort Union coals are also present in the Big Horn Basin, the Bull Mountain Basin, and Park and Gallatin counties where they are prospective for CBM resources.

Wasatch Formation

The Eocene Age Wasatch is present in the Montana portion of the PRB as fine-to medium-grained sandstone lenses and channel-fill interbedded with silstones, shales, and minor coal. The thickness of the Wasatch Formation ranges from near zero at the outcrop edge to 400 feet near the southern state boundary (Roberts et al. 1999a). It is present in outcrop in the extreme southwest corner of the basin where it overlies the Fort Union.

Quaternary Alluvium

Quaternary age sediments are those that are Pleistocene (the latest glacial episode) and Recent (post-glacial episode) in age; the sequence is dominated by events and effects associated with continental glaciation, including glacial till and exaggerated peri-glacial valley fill. Quaternary sediments in the PRB and most of the state are present as variable fill in stream and river valleys. Quaternary Alluvium consists of unconsolidated sand, silt, and gravel that make up the floodplains and stream terraces of creek valleys in the PRB (BLM 1999b). Thickness is highly variable, but maximum thickness is not expected to exceed 90 feet. Lithology is somewhat dependent on bedrock outcrop; alluvium overlying the Tertiary strata are mostly fine-grained to medium-grained sands and silts. Coarser-grained alluvium may be associated with some of the larger rivers where provenance has been outside the PRB (Hodson et al. 1973). Alluvium aquifers are largely unconfined and connected to active river flow. Because alluvial aquifers can deliver large quantities of water to water supply wells, they are important stratigraphic features. They are also important to this report because they are vulnerable to impact and are often connected to surface water resources. Alluvial aquifers can be impacted by surface activity and can act as a conduit to carry those impacts to valuable surface water resources.

HYDROLOGY

Hydrology identifies aquifers (porous units containing water) and aquitards (non-porous strata that serve to confine and separate aquifers) in a geographic and vertical sense. Aquifers can contain drinkable water, brackish water of limited usability, or salt water. In the EIS planning area, several formations contain drinking water but show variable reservoir quality and water quality. The Montana portion of the PRB includes many aquifers that represent different hydrologic flow regimes. The basin includes unconfined aquifers as well as confined, bedrock aquifers. Aquifers range from the unconfined Quaternary alluvium in the streambeds of rivers and creeks to the Mississippian Age Madison Formation in excess of 10,000 feet below the surface. The water quality within these aquifers ranges from less than 300 mg/L TDS to more than 30,000 mg/L TDS (Bergantino 1980). The aquifers also vary in depth from the basin center to the margin. Coal aquifers are widespread, supply large numbers of water wells, and will be impacted most by CBM production.

Exhibit 15 lists the significant aquifers in the Montana portion of the PRB that will be discussed throughout this report. The wells are almost exclusively completed in the shallow aquifers (< 500 ft depth) with the Tongue River Coals being the major aquifers. Wells completed in the major aquifers are limited in geographic distribution – Alluvium wells are distributed along principle rivers and streams, coal wells are arrayed in two principal bands corresponding to two stratigraphic packages, and Cretaceous sand wells are largely limited to the rim of the PRB. Only a very few wells utilize the Wasatch Formation, an aquifer that is more widespread and more important in the southern part of the PRB. A small number of wells near the edges of the PRB use the Cretaceous aquifers. A few wells utilize the sands in the Lebo and Tullock Members. The majority of water wells are completed in the Tongue River coals. The coal aquifers are the nost important to this report since they hold the CBM resource and production of the gas will directly impact coal seam aquifers. CBM production inevitably impacts coal seam aquifers within and around CBM producing fields. CBM production may also impact Alluvium aquifers where they intersect impacted coal seams.

EXHIBIT 15 - AQUIFERS IN THE MONTANA PORTION OF THE PRB

Summary of Montana PRB aquifers and associated data for approximate depth and number of current wells listed in the MBMG database.

AGE	AQUIFER	APPROXIMATE DEPTH	NUMBER OF WELLS IN THE MBMG DATABASE
Quaternary and Recent	Quaternary Alluvium	Surface to 90 feet	198
	Wasatch	100 feet	6
Tertiary	Tongue River Coals	50 to 400 feet	957
	Lebo/Tulloch	100 to 400 feet	306
	Hell Creek/Fox Hills	100 to 500 feet	199
Cretaceous	Judith River	2500 feet	1
Cretaceous	Eagle	2700 to 5700 feet	0
	Dakota/Lakota	5600 to 8600 feet	0

Note: MBMG = Montana Bureau of Mines and Geology

Dakota/Lakota Formation

This formation is present at approximately 5,600 feet bgs in the northern part of the PRB and at approximately 8,900 feet bgs at the southern Montana state line. The Dakota is present across the basin and commonly contains more than 50 feet of sand.

Eagle Formation

This sand zone is present at the south edge of the Montana portion of the PRB at approximately 5,700 feet bgs and at approximately 2,700 feet bgs on the northern edge of the basin. The Eagle exhibits scattered sand development. In Gallatin, Park, and Blaine counties, the Eagle Formation contains coal seams; in these counties CBM production may impact the Eagle sand aquifers.

Judith River Formation

This formation shows in excess of 40 feet of total sand at a depth of approximately 2,150 feet bgs near the Ashland coal area at the northern edge of the PRB. Sand in this formation is not present everywhere and produces water of only moderate quality; water of this quality could not be used for drinking or irrigation without treatment.

Fox Hills—Hell Creek Formations

These Cretaceous sands combine to form the principal aquifer in southeastern Montana (Miller 1981). Water wells into the joined sands can yield as much as 40 gpm. Municipal supply wells can yield more than 200 gpm (Miller 1981). Water quality is generally lower than in either the Fort Union or Quaternary Alluvium. The Fox Hills/Hell Creek aquifer is separated from the coal aquifers in the Fort Union by over 500 feet of fine-grained sediments in the Tullock and Lebo Members; these aquitards are not penetrated by CBM development wells and will, therefore, maintain their integrity. CBM production and drawdown of coal aquifers will not impact water wells using these Cretaceous or deeper aquifers.

Fort Union Formation

The Fort Union Formation contains minor sands and all of the water producing coal beds in the Montana PRB. Coal beds are the most-used aquifers in the Montana PRB (MBMG 2001) where they are largely used for stock watering. Yields can be as high as 150 gpm but average approximately 10 gpm (Bergantino 1980). Within the PRB, coalbed water wells are often less than 100 feet deep but can be as deep as approximately 400 feet (MBMG 2001). Coal reservoir parameters are listed in Exhibit 16 below. The thickness information provided appears to be highly variable but this may not be the truth; previous analysis may have combined thinner coal seams that are separated by thin shale layers that form local aquitards, but appear to be minor lenses in cores or wire-line logs. Porosity data is

largely a measure of fracture porosity that is notoriously difficult to measure. The other parameters listed are also dependent upon fracture or cleat density. A more basic uncertainty is the unknown influence of coal bed methane on reservoir characteristics – is there a genetic connection between reservoir parameters and the presence of significant quantities of methane? Do the same coal seams, in a non-producing condition, have significantly different characteristics? There is insufficient data in the Montana portion of the PRB to provide answers. CBM produced water will be discussed in more detail within the impacts chapter of this Technical Report.

EXHIBIT 16 - PUBLISHED RESERVOIR PARAMETERS FOR ACTUAL AND POTENTIAL CBM RESERVOIRS

Reservoir parameters for several coal bed aquifers throughout the Montana portion of the PRB as compared to the Wyodak-Anderson Wyoming EIS data.

COAL SEAM	THICKNESS	TRANS- MISSIVITY	Hydr. Cond.	POROSITY (%)	STORAGE COEFF.
Anderson – Dietz (CX Ranch) Redstone 1999	70'	300 ft²/day	3.37 ft/day	2.0	2.18E-5
Knobloch (Montco Mine, permitted but not opened) (MDSL, 1982)	44'	58 ft ² /day	2.3 ft/ day	2.0	1.2E-4
Knobloch (Ashland Mine, not permitted) (Woessner, et al, 1981. EPA-600-7-81-004a.)	54'	100 ft ² /day	2 ft/day	2.0	5.0E-5
Wyodak-Anderson (BLM, 1999a) For comparison only	Variable		2.0E-5 m/sec (5.67 ft/day)	1.0	1.0E-4

Groundwater conditions described for the Montana Portion of the PRB Resource Management Area (RMA) also exist within the Bull Mountains Basin in the Billings RMP area (Noble 1982). In this basin, Quaternary Alluvium and shallow Fort Union Formation coal and sand aquifers are important sources of water. Coals in the Billings RMP area are adjacent to sand aquifers and are aquifers themselves; water production from Bull Mountains Basin coals is likely to cause drawdown to nearby water wells similar to the Montana portion of the PRB in addition to possibly impacting vertically adjacent aquifers.

Wasatch Formation

Only a very small portion of the Montana PRB contains Wasatch bedrock; the formation has been either eroded or was not deposited over most of the area except within the very center of the basin. In the Wyoming portion of the PRB, Wasatch sands are significant aquifers that can support wells that yield in excess of 500 gpm (BLM 1999b).

Quaternary Alluvium and Associated Terrace Deposits

These clastic sediments are unconfined and in connection with permanent or significant ephemeral rivers and streams. Thickness can exceed 90 feet, but most average less than 30 feet (Bergantino 1980). Water yields average 25 gpm, but can be considerably higher (Bergantino 1980). Quaternary alluvium is the most-used aquifer in the Great Plains portion of Montana (Noble et al. 1982). In the Montana PRB, a total of 198 wells are identified as being screened in the Quaternary Alluvium (MBMG 2001). These wells are largely used for domestic supply, but are also used for publicly owned water systems, livestock, and irrigation. In the Montana PRB, Fort Union Formation coals outcrop in the valleys of streams and are in contact with alluvium. At the edge of the basin, Lebo and Tullock aquifers, as well as Cretaceous aquifers, outcrop in streambeds.

WATER WELLS

Exhibit 17 is a water well map of the Montana portion of the PRB. Not all wells plotted in Exhibit 12 are identified on this map because owners have not reported information on all water wells to the state. Wells completed in the major aquifers are limited in geographic distribution:

- Alluvium wells are distributed along principle rivers and streams although several wells identified as alluvium appear away from present streams; these are either misidentified or are completed in alluvial deposits associated with abandoned, dry stream valleys.
- Coal wells arrayed in two principal bands corresponding to two stratigraphic packages the Anderson-Dietz at the top of the Tongue River Member and limited to the center of the basin, and the Knoblock at the base of the Tongue River Member and occurring throughout most of the basin.
- Lebo and Tullock wells appear mostly beyond the outcrop of the Tongue River Member beyond which no coals are present in the subsurface.
- ex Cretaceous sand wells largely limited to the rim of the PRB where they are shallowest.

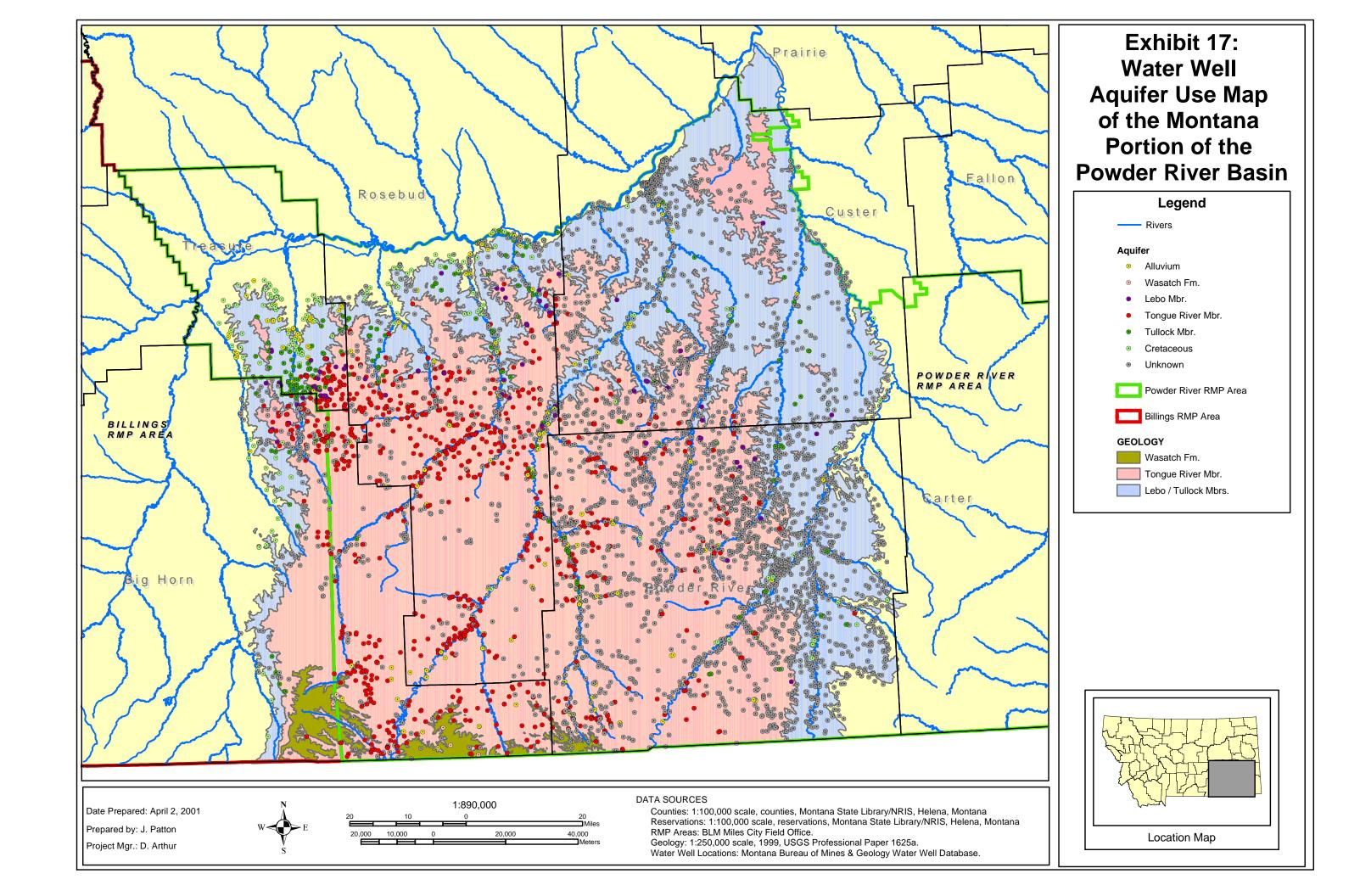
The coal aquifers are of special interest since they hold the CBM resource and production of the gas will directly impact coal seam aquifers. CBM production inevitably impacts coal seam aquifers. CBM production may also impact Alluvium aquifers where they intersect coal seams. The most important groundwater-surface water interaction concerning the effects of CBM production is the exchange of water between coal seams and surface water via Alluvium. Exhibit 18 is a map of coal and clinker deposits in the Montana portion of the PRB. Several bands of coal seam development – Anderson, Knoblock, and Colstrip – outcrop as clinker in the watersheds of major streams. These clinkers often give rise to springs that feed into rivers and alluvium. During periods of little run off, such as late winter when streams and rivers are at baseflow, streams are particularly vulnerable to impact from surface recharge by low quality coal aquifer water. At times of high run off, rivers and streams often have sufficient flow to dilute the coal aquifer water coming via clinker-fed springs.

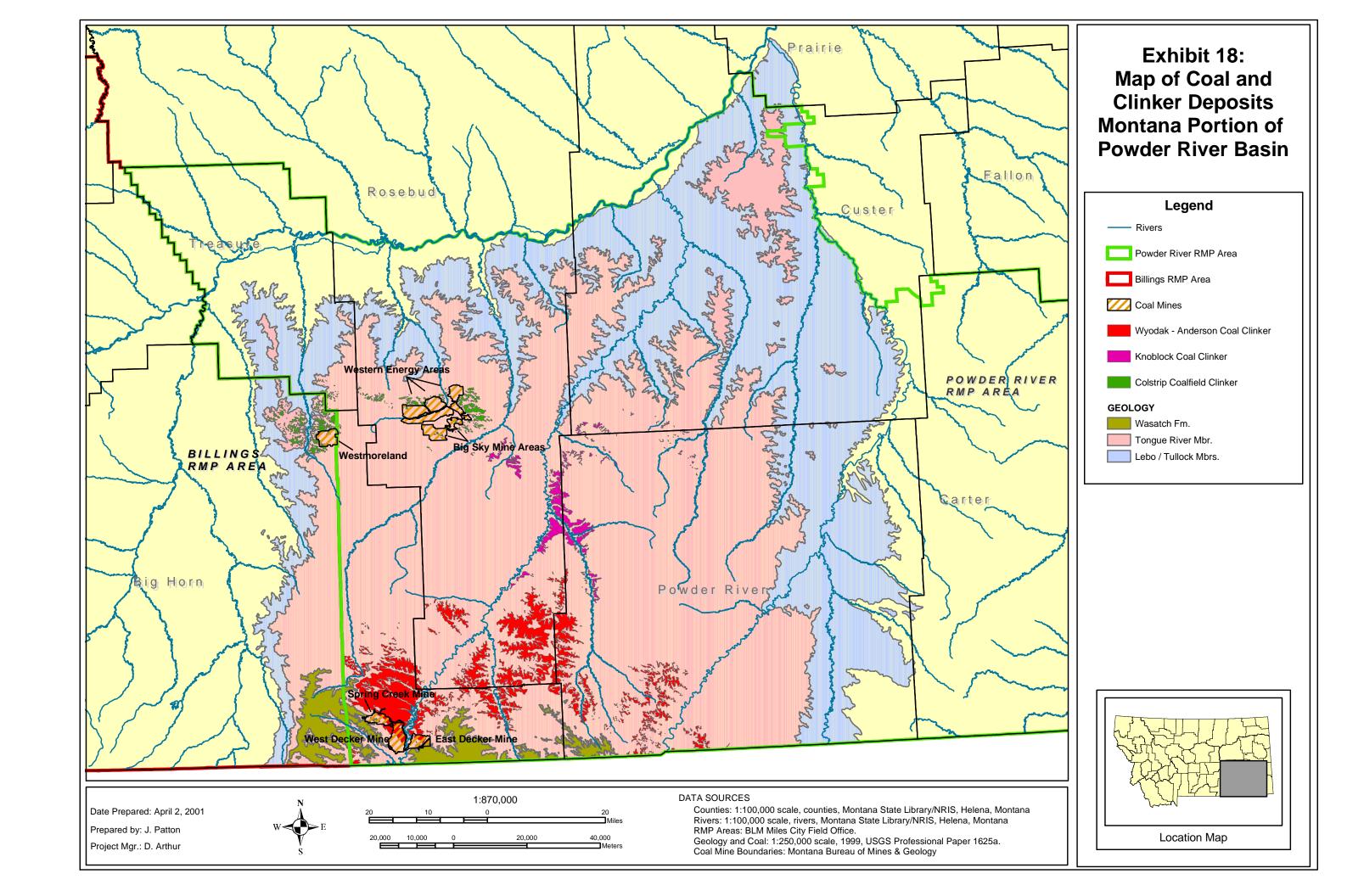
ARTIFICIAL PENETRATIONS

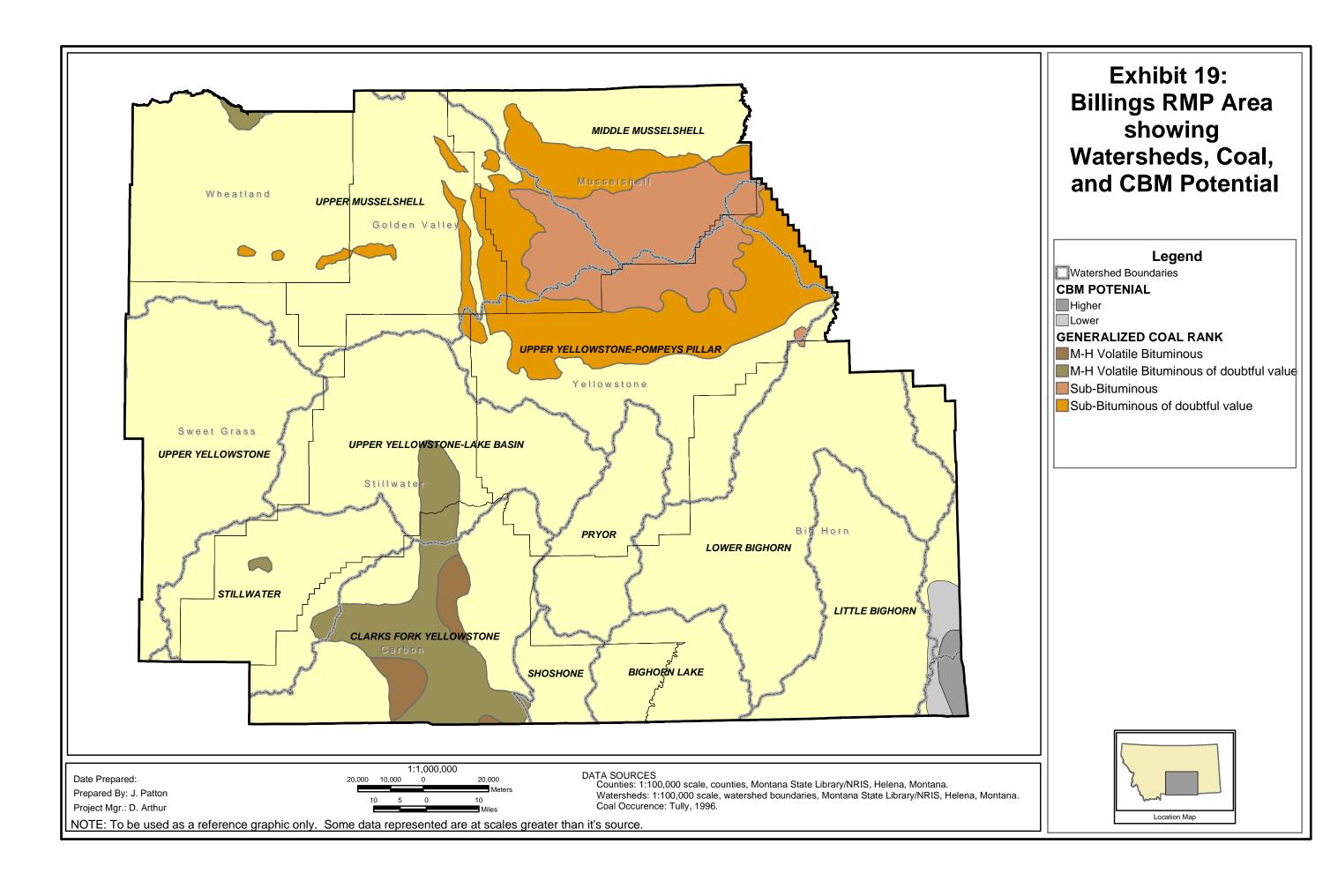
Artificial penetrations including geotechnical boreholes, unplugged oil and gas wells, seismic shot-holes, or open water wells are able to conduct water from the surface into aquifers or can conduct water between aquifers. A penetration open to an aquifer and to the surface can allow low quality surface water (CBM water being discharged to an impoundment or water running off cropland laden with fertilizers and pesticides) to enter the aquifer. A penetration open to more than one aquifer can allow water to flow between the aquifers; if one of the aquifers is being produced for CBM, the coal seam could act as a sink to steal water from the other open aquifer. Open artificial penetrations are a difficult threat to gauge and predict; isolated, forgotten water wells can occur anywhere. Oil and gas wells drilled prior to state casing and plugging regulations are a threat that can be more easily predicted. Artificial penetrations are likely a remote threat to water resources in the PRB but are perhaps an important consideration elsewhere in the state. If, during CBM productions, an open borehole were discovered, it would be the responsibility of the original owner of the borehole or the CBM operator to suitably plug the hole.

WATERSHEDS

Watersheds are important to predicting the impacts from CBM development in Montana. Water resource factors such as water quality, water use, and potential impacts will be discussed throughout this report in terms of watersheds. Each watershed is drained by a single stream or river and each is bounded by a no-flow topographic boundary. Streams and rivers are profoundly influenced by their watersheds; in particular water volume and water quality vary from base flow conditions to high-flow conditions under the control of runoff from land surfaces and recharge to rivers by aquifers. Exhibit 3 in Chapter 1 highlights the watersheds in the PRB along with potential CBM areas. The areas of highest potential for CBM development fall within the northern portion of the Upper Tongue River Watershed, the southern section of the Lower Tongue River Watershed, the western section of the Middle Powder River Watershed, and the eastern section of the Rosebud Watershed. The current CBM production area in the Montana PRB lies within the Upper Tongue River Watershed. It should be noted that the watersheds along the southern boundary of the Montana PRB drain to the north and may already be impacted by CBM development in Wyoming. Exhibit 19 likewise highlights watersheds in the Billings RMP area. The areas of highest potential for CBM development fall within the northern section of the Upper Yellowstone-Pompeys Pillar Basin, the eastern Upper Musselshell Watershed, and the southern Middle Musselshell Watershed.







CHAPTER 4 - WATER USE AND QUALITY

INTRODUCTION

Water use and quality are key elements of understanding the relation of Coal Bed Methane (CBM) development and production to water resources. The type and magnitude of potential impacts due to the CBM development vary greatly throughout the CBM emphasis area and especially in the Montana portion of the Powder River Basin (PRB). In the Montana portion of the PRB, coal seam aquifers are relatively shallow and are relied on for a variety of uses, including industrial, irrigation, stock, public, and domestic. These uses can be influenced by the depth of the aquifers, water quality, and deliverability.

Although many coal seam aquifers in the Montana portion of the PRB are sufficiently shallow and of sufficient quality to attract usage, coal seams in other portions of the CBM emphasis area are much deeper and are not used to any significant extent. For instance, coals in Stillwater, Park, and Gallatin counties exist at depths up to 2,000 feet below ground surface (bgs) (Roberts and Rossi, 1999). In these areas, water supplies other than coal seam aquifers appear to adequately meet current and future anticipated demands.

For the Montana portion of the PRB, groundwater usage can be visually represented using spatial analysis. Exhibit 20 shows a spatial representation of available water well types and locations throughout the boundaries of the PRB in Montana. This exhibit also shows outcrop geology, rivers, the Crow and Northern Cheyenne Indian Reservations, and boundaries of the Powder River and Billings Resource Management Planning (RMP) areas. Although important, water well information for the Crown and Northern Cheyenne Indians Reservations is believed to be somewhat incomplete. The true degree of incompleteness (i.e., how many wells are missing from this inventory) is unknown.

Further visual inspection of Exhibit 20 shows the majority of water supply wells in the Montana PRB are used for stockwater with smaller numbers of domestic use wells. There are also trends showing that many of the water wells in the study area fall along riverways, suggesting that source water for these wells is the alluvium aquifer and not coal seam aquifers. The largest density of wells primarily exists in the central portion of the basin along a path that generally stretches from southeast Treasure County to east-central Powder River County. Water supply wells are generally more sparsely scattered in the southwestern portion of the PRB in Montana, which include the area in the vicinity of the only commercially active CBM producing field in the state (i.e., CX Ranch).

In addition to water supply wells, natural springs play an important role with respect to water usage through the Montana portion of the PRB. Spring locations were not included in Exhibit 20 or another exhibit due to the lack of inventory data available for natural springs in the area. Therefore, it is important to also be aware of the fact that natural springs are yet another important water resources issue that could relate to CBM activities.

In addition to evaluation of groundwater use, surface water use is also a significant water resources issue throughout the CBM emphasis area and in the Montana portion of the PRB. Both groundwater and surface water usage varies widely by watershed with some areas having little water use with respect to water use applications, including industrial and agricultural use. In 1995, the United States Geological Survey (USGS) assessed surface water usage that included those watersheds in the PRB of Montana (USGS 1995).

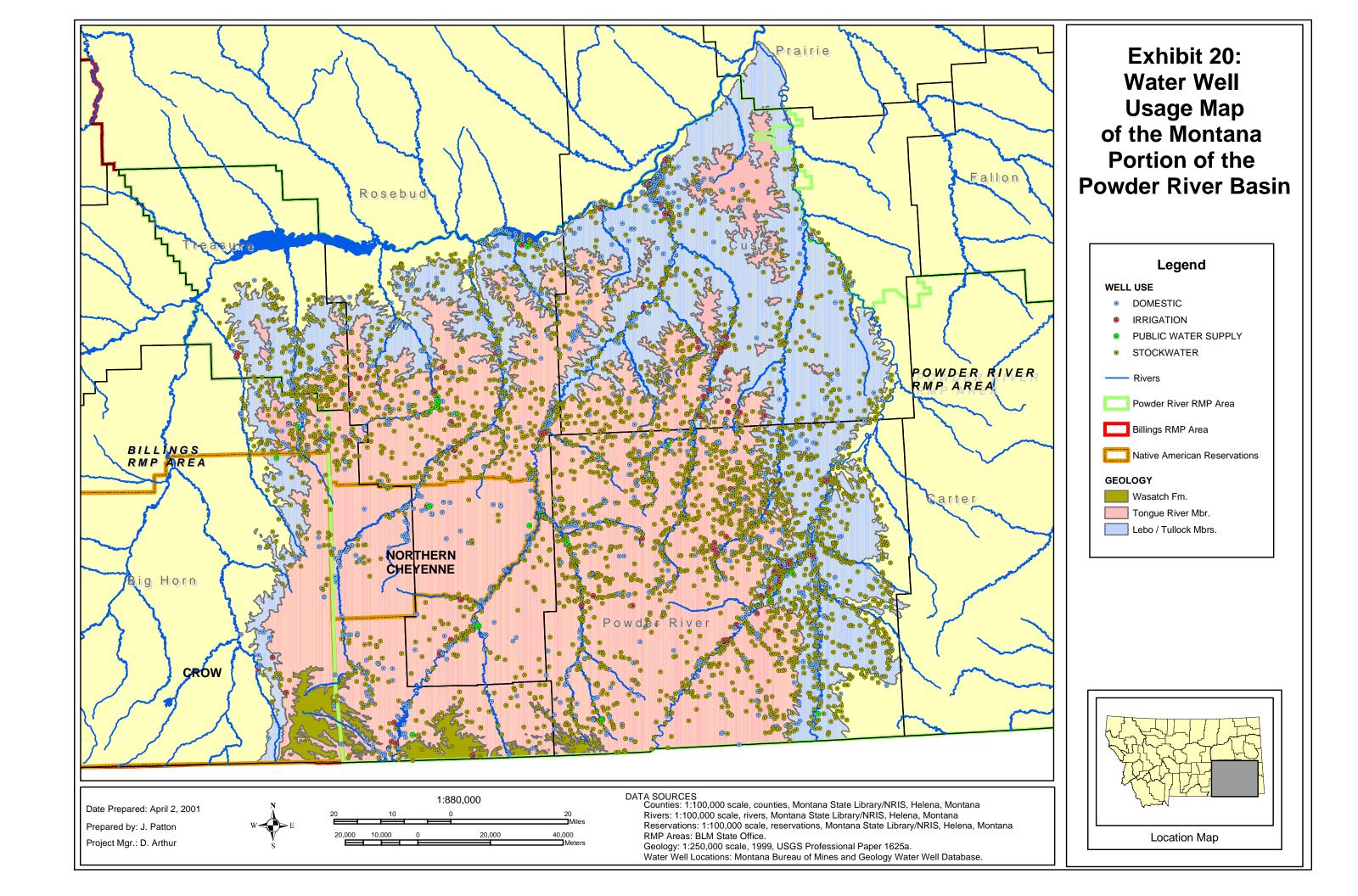


Exhibit 21 summarizes surface water withdrawal rates for the various watersheds of the Montana PRB from the above referenced USGS study. Withdrawal rates vary by watershed from approximately 37 cubic feet per second (cfs) in the Middle Powder watershed to nearly 1,000 cfs Little Big Horn watershed.

EXHIBIT 21 - WATER WITHDRAWAL RATES BY WATERSHED, MONTANA PRB

Summary of USGS data for surface water withdrawal rates for the various watersheds in the Montana portion of the PRB.

WATERSHED	AVERAGE SURFACE WATER WITHDRAWAL RATE IN 1994 (USGS, 1995)
Little Big Horn	975 cfs
Mizpah	640 cfs
Middle Powder	37 cfs
Rosebud	43 cfs
Upper Tongue	276 cfs
Lower Tongue	460 cfs

WATER QUALITY

Exhibit 22 shows select groundwater quality data collected from water supply wells located throughout the Montana portion of the PRB by source aquifer. Total dissolved solids (TDS) and Sodium Adsorption Ration (SAR) were selected to provide a generalized characterization of groundwater in the area. Data analysis shows water to be of poor to moderate quality with TDS concentrations that range throughout the study area from a county-average low of approximately 890 mg/L to a county-average high of nearly 2,500 mg/L. Similarly, SAR ranges from a county-average low of approximately 5 to a county-average high of approximately 64. Water quality in the Fort Union Formation, which contains all of the potential CBM producing horizons, has a basin-wide average TDS and SAR of approximately 1,892 mg/L and 18, respectively

EXHIBIT 22 - GROUNDWATER QUALITY FOR THE MONTANA PORTION OF THE POWDER RIVER BASIN

Selected groundwater quality data collected from water supply wells located throughout Montana PRB

	JUDITH	RIVER	HELL CREEK /FOX		FORT UNION		QUATERNARY		
	FORMA	TION	HILLS FO	HILLS FORMATION		FORMATION		ALLUVIUM	
County	Avg. TDS (mg/L)	Avg. SAR	Avg. TDS (mg/L)	Avg. SAR	Avg. TDS (mg/L)	Avg. SAR	Avg. TDS (mg/L)	Avg. SAR	
Big Horn	936	54	1440	14	1658	8	2118	5	
Rosebud	2465	31	1376	35	1595	16	1516	9	
Powder River	No data	No data	890	35	1882	15	2783	5	
Custer	No data	No data	896	37	1810	31	1665	8	
Treasure	2312	64	1985	56	1782	32	2437	10	
Weighted Average	2100	42	1148	37	1892	18	2014	7	

Note: Avg. TDS = Average Total Dissolved Solids, Avg. SAR = Average Sodium Adsorption Ratio

Groundwater quality for the Montana PRB can be further analyzed through review of monitoring data near coal mining areas. Exhibit 23 presents a summary of groundwater quality statistics for various coal seam aquifers. This exhibit shows that average TDS varies from approximately 900 mg/L (Pearl Mine) to approximately 2,800 mg/L (Decker Mine). Similarly, average SAR values vary from approximately 2 to 100. Water from the Big Sky mine,

located approximately 50 miles north of Decker, near Colstrip, Montana, appears to be much less saline than coal aquifer water in the vicinity of the Decker mine. Groundwater from the Carbone area, on the north edge of the Spring Creek mine and just north of the CX Ranch field, has SAR values exceeding 100 – which are very high for the Montana portion of the PRB. Groundwater from the Rosebud mine, near Colstrip, Montana, also appears to be less saline than other coal mining areas.

EXHIBIT 23 - SUMMARY GROUNDWATER STATISTICS OF COAL AQUIFERS FROM COAL MINES IN THE PRB

Summary of groundwater quality statistics for various coal seam aquifers in the Montana portion of the PRB.

COAL MINE AREA	AQUIFER	TOTAL DISSOLVED SOLIDS MG/L (samples)	SAR (samples)
	Alluvium	1516 (4)	1.6 (4)
Pearl Mine, Big Horn County	G – Coal	401 (2)	34 (2)
(Hedges, Van Voast, and	M – Coal	1086 (11)	22 (11)
McDermott, 1976)	O – Coal	1249 (3)	41 (3)
	Coal average	912	32
	Alluvium	1762 (64)	1.5 (64)
	Overburden	1276 (53)	1.3 (53)
Big Sky Mine – Area B	Rosebud Coal	2324 (63)	5 (63)
Rosebud County (MDSL, 1988)	McKay Coal	2376 (66)	9.5 (66)
	Sub-McKay Coal	2343 (98)	7 (98)
	Coal average	2348	7
	Alluvium	827 (35)	9.6 (35)
Carbone Amendment Area	Overburden	1578 (10)	211 (10)
Big Horn County	Anderson	1185 (70)	74 (70)
(BLM, 2000c)	Canyon	1070 (2)	129 (2)
	Coal average	1128	101
	Alluvium	2647 (610)	1.8 (778)
Rosebud Mine, Rosebud County	Rosebud Coal	1311 (446)	1.3 (520)
(MDEQ, Appendix B)	McKay Coal	1800 (482)	2.04 (582)
(MDLQ, Appendix B)	Sub-McKay Coal	1654 (166)	6.06 (229)
	Coal average	1578	2.44
Dealer Mine Die Hern County	Alluvium	3,420-4,340 (42)	0.3-8 (42)
	Anderson	502-3,400 (82)	8-77 (82)
Decker Mine, Big Horn County (MDEQ, Appendix C)	Dietz	430-6,520 (261)	1-131 (261)
(MDEQ, Appendix C)	Canyon	1,060-2,860 (54)	14-72 (54)
	Coal Average	2,816	38.91

Additional groundwater quality data is available from samples collected from CBM production at the CX Ranch field near Decker, Montana. Exhibit 24 presents detailed analytical data from water collected as part of CBM production operations. Both TDS concentrations and SAR values align with water quality data obtained from other sources with TDS concentrations ranging from approximately 1,400 to 1,580. SAR values ranged from approximately 33 to 47. Several other water quality parameters are shown in Exhibit 24. This data shows that fluoride, aluminum, lead and barium have exceeded federal drinking water standards. Water from these Fort Union coals seam aquifers also exceeds livestock watering guidelines for aluminum and fluoride.

EXHIBIT 24 - DETAILED PRODUCED WATER QUALITY FROM THE CX RANCH CBM FIELD

Results of CX Ranch CBM production water compared to National and State standards and various other coal seam water analytical data.

water analytical d		3.670 337			3.5	
	NATIONAL DRINKING	MT. WATER QUALITY	CX RANCH	DIETZ COAL WATER	MONARCH COAL WATER	CARNEY COAL WATER
ANALYTE	WATER	STDS. FOR	AVERAGE	SW-SW SEC	SW-SW	SW-SW
ANALITE	STANDARDS	LIVESTOCK	(MDEQ,	20-9S-40E	SEC 20-9S-40E	SEC 20-9S-40E
	(primary	PPM	2000)	(Williams,	(Williams,	(Williams, 2001)
	unless noted)	(MSU 2001)		2001)	2001)	
TDS mg/L	500	10,000	1,400	1,580	1,460	1,420
	(secondary)					
SAR			47	42.3	46.6	33.3
Sodium mg/L			558	603	567	547
Ammonia,			2.0			
Total mg/L						
Ammonia,				2.42	2.35	2.10
nitrogen mg/L						
Bicarbonate as				0.0	1,600	1,550
HCO3 mg/L					,	,
Chloride mg/L	250		19	19.9	19.7	19
	(secondary)					
Fluoride mg/L	2.0	2	2.5	1.43	2.68	3.66
I luolide ilig/L	(secondary)	2	2.3	1.43	2.00	3.00
Phosphorous,	(secondary)			0.120	90	800
total mg/L				0.120	90	800
Sulfate mg/L	250			< 0.01	<0.01	< 0.01
Surface flig/L				<0.01	<0.01	<0.01
A.1 .	(secondary)		0.05	0.050	1.20	44.7
Aluminum,	0.05 to 0.2	5	0.05	< 0.050	1.38	44.7
total mg/L	(secondary)	0.2	0.001	0.001	0.001	0.020
Arsenic mg/L	0.05	0.2	0.001	<0.001	<0.001	0.028
Barium mg/L	2.0		0.5	0.5	0.6	2.2
Beryllium mg/L	0.004	_	0.0005			
Boron mg/L		5	0.07	0.05	0.08	0.10
Cadmium mg/L	0.005	0.05		< 0.0002	< 0.0002	0.0015
Chromium mg/L		1		< 0.001	0.002	0.064
	0.1					
Calcium mg/L				9.4	7.5	10.9
Copper mg/L	1.0	0.5	0.001	0.103	0.013	0.112
	(secondary)					
Lead mg/L	0.015	0.05	0.002		0.005	0.136
Iron,	0.3		0.03			
dissolved mg/L						
Iron, total mg/L			0.125	0.310	1.4	23.0
Magnesium mg/L				3.6	2.3	5.8
Manganese mg/L	0.05		0.01	< 0.01	0.020	
Mercury mg/L	0.002	0.1	<u> </u>	< 0.00006	< 0.00006	< 0.00006
Molybdenum	-			< 0.02	<.02	< 0.020
mg/L					2	
Nickel mg/l				< 0.01	< 0.01	0.060
Potassium mg/L				6.1	6.5	8.8
Selenium mg/L	0.05	0.5		< 0.005	< 0.005	0.007
Strontium mg/L	0.03	0.5	0.43	\0.003	\0.00 <i>3</i>	0.007
Radium mg/L	5 pCi/L		0.43			
Vanadium mg/L	3 pCI/L	0.1	0.2	< 0.02	< 0.02	0.090
Zinc mg/L	5	24		0.03	0.02	0.290
	(secondary)					

CHAPTER 5 - WATER RESOURCES IMPACT ISSUES

INTRODUCTION

The production of coal bed methane (CBM) has the potential to impact water resources in a variety of ways. Drawdown of coal seam aquifers is an unavoidable impact because the de-pressurization of coal seams is inherent to the process of CBM production. Once brought to the surface during production operations, produced water is essentially a waste bi-product that must be disposed of. Options for disposal include discharge to land or surface water bodies, re-injection, or one of many beneficial use options (e.g., stock watering, controlled irrigation, dust control, storage impoundments, etc.).

The combination of potentially substantial water volumes combined with relatively poor to moderate water quality characteristics emphasizes the needs to closely evaluate and monitor CBM development and production. Depending on the area, groundwater and/or surface waters may vary in potential vulnerability. To fully understand these potential vulnerabilities and impacts, analysis of both groundwater and surface water is required.

GROUNDWATER DRAWDOWN FROM CBM DEVELOPMENT

Groundwater drawdown from CBM production has been documented inside and adjacent to existing production in Montana. CBM production in the PRB requires drawdown of coal aquifers within the producing field in order to liberate methane. Water wells adjacent to but outside of a producing CBM field may also be adversely impacted. Drawdown can be documented by way of dedicated monitoring wells or by gauging private water wells. In Montana's CX Ranch CBM field, the MBMG has installed monitoring wells designed to track drawdown due to the coal mines in the area as well as CBM development.

Exhibit 25 is a location map of monitoring wells, CBM wells, and coal mines near Decker, Montana. This exhibit show the spatial relationship between monitoring stations and both coal mine development and active CBM production at the CX Ranch field. Both water level and water quality data have been collected at the monitoring wells identified, although some are currently inoperative. Some of these monitoring wells are periodically checked and sampled. Monitoring data for these wells were obtained from the Montana Bureau of Mines and Geology.

Hydrographs of 13 separate monitoring wells in the area of the CX Ranch field are presented in Appendix D. Monitoring well WR-51 is located within the boundaries of active commercial CBM production. These hydrographs document drawdown impacts from CBM production at the CX Ranch field at distances of approximately 0.0 to 4.2 miles away from active production. The recorded drawdowns occurred within two years of the start of CBM production. Some monitoring wells in or near CBM operations (e.g., WR-51, WR-53 and WR-55) indicate that sudden drawdowns can occur as a result of CBM production coupled with coal mine withdraws. Other monitoring wells located further from CBM operations at the CX Ranch field still showed noticeable reductions without signs of stabilizing considering currently available data and information. Some monitoring wells showed no evidence of drawdown from CBM activity.

When evaluating these hydrographs, it is important to recognize that CBM operations may be ongoing for 15 to 20 years. The combination of extraction rates and duration has escalating effects that may cause groundwater drawdown impacts for several miles from active CBM producing operations. Predicting the actual outer distance of drawdown impacts within coal seams is difficult across the PRB in Montana because the basin has only a fraction of the development that may occur. Furthermore, the PRB in Montana is a geologically complex area with relatively sparse information regarding hydrogeology.

Exhibit 26 summarizes the water level data of 14 monitoring wells in or adjacent to the CX field for which coal aquifer data is available. Those wells closest to the center of CBM development tend to show drawdown at the earliest date, however there are exceptions. The degree of draw-down recorded appears to be due to water production from the nearly 200 CBM wells now on-line at the CX field as summarized above; production began with the drilling of the first CBM wells in March 1998 and first pumping in December 1998 (Williams 2001).

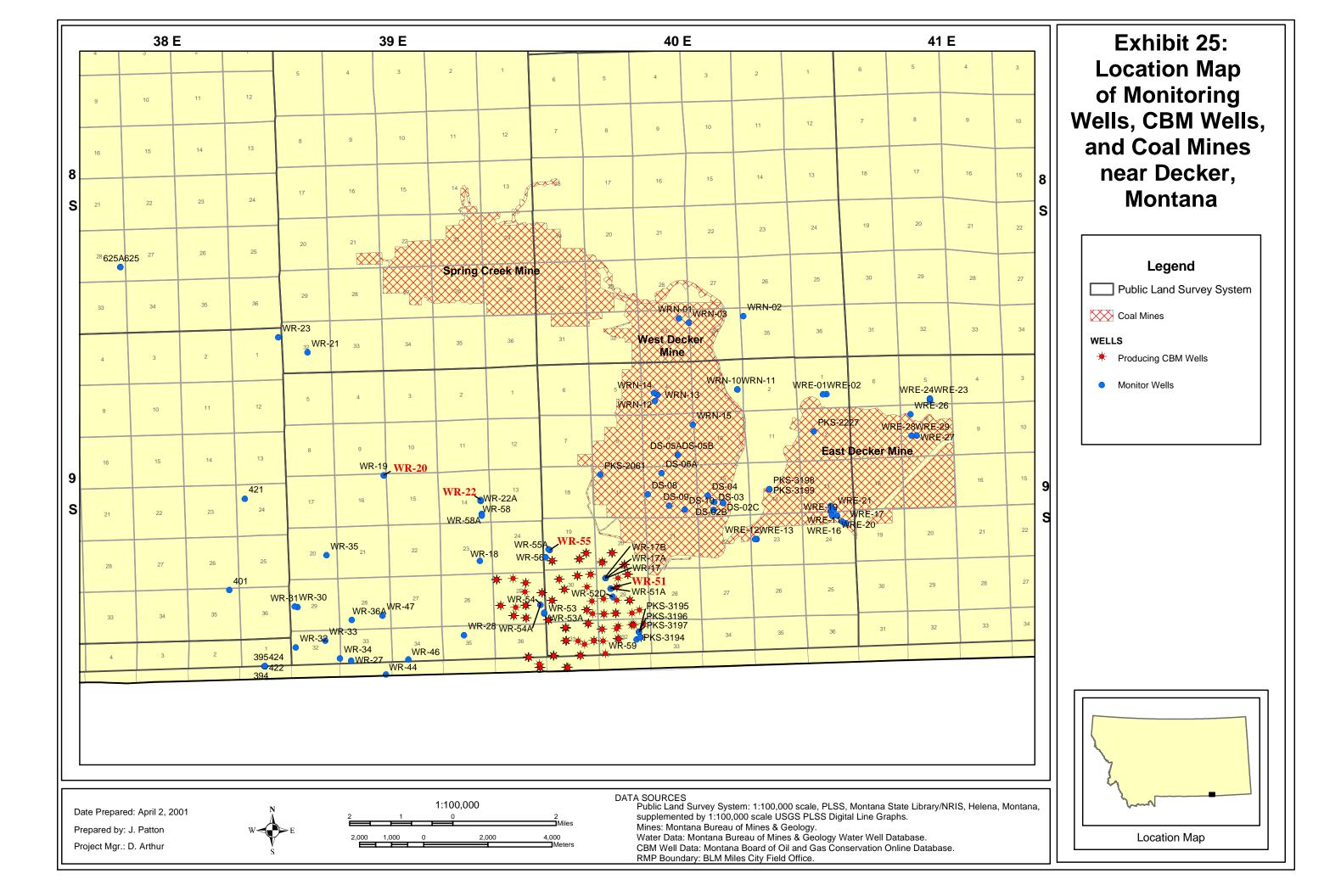


EXHIBIT 26 - SUMMARY OF WATER LEVEL DATA FROM CX FIELD MONITORING WELLS

Statistics on the 13 hydrographs in the vicinity of CX Ranch CBM Field

MONITORING WELL	DISTANCE FROM NEAREST CBM WELL	DATE OF ONSET OF DRAW-DOWN	TIME FOR DRAW- DOWN TO REACH WELL	MAXIMUM DRAW- DOWN
WR-17	0.0 miles	10/1999	11 months	21 feet
WR-51	0.0 miles	1/1999	1 month	111 feet
WR-53	0.0 miles	10/1999	11 months	74 feet
WR-53A	0.0 miles	11/2000	24 months	2.0 feet
WR-54	0.0 miles	10/1999	11 months	38 feet
WR-55	0.2 miles	11/1999	12 months	51 feet
WR-28	0.92 miles	None	=	0.0 feet
WR-22	1.8 miles	3/2000	16 months	10 feet
DS-05A	2.40 miles	None	-	0.0 feet
WR-27	3.12 miles	None	-	0.0 feet
WR-19	3.68 miles	None	-	0.0 feet
WR-20	3.68 miles	None	-	0.0 feet
WRE-10	4.20 miles	None	-	0.0 feet

Monitoring well WR-51, screened in the D-2 coal, is in the midst of CBM wells and showed the first signs of drawdown immediately after onset of pumping in January 1999. WR-51 currently shows 111 feet of drawdown but is probably not at equilibrium and is likely to show more drawdown in the future.

Monitoring well WR-55, screened in the D2 coal, which is approximately 0.2 miles beyond current CBM development, showed drawdown in November 1999; this well currently shows a drawdown of 51 feet, but also is not at equilibrium and drawdown may increase with continued CBM production.

The radius of impact to area water levels has moved out at least 1.8 miles to well WR-22, screened in the D-1 and D-2 coals. The WR-22 first saw drawdown in March 2000 but shows only approximately 10 feet of drawdown.

It is unclear what the limit of drawdown will be as the field continues to produce CBM. It may be that as pumping rates drop in the CX Ranch Field, the drawdown radius of impact may cease spreading and may stabilize.

The CX Ranch is still being developed and producing wells are being added. Full extent of CBM development and full extent of offsite aquifer drawdown cannot be estimated at the present time. It is possible that if further development doesn't take place, the WR-22 well may not be drawn down beyond its present point. It is also possible that if more CBM wells are drilled, then WR-22 may be surrounded by CBM wells and drawdown will likely increase more rapidly.

Groundwater drawdown can result in wide-ranging methane migration phenomena under adjacent leases including methane liberation into in nearby water wells, coal fires, etc. have been observed in other coal basins. The PRB is sufficiently different from the San Juan Basin (SJB); however, it may not support methane migration away from aquifer drawdown. Methane liberation into non-produced water wells has been demonstrated at CX Ranch, the extent of the phenomenon is unknown at the present time.

The San Juan Basin (SJB) has experienced gas seeps and coal fires that appear to be increasing in number in concert with increasing CBM production (BLM, 2000b). It is hypothesized that nearby CBM production has intensified seep activity. Specifically, lowering of the water table in the monocline by downdip dewatering of coal beds is postulated to allow CBM to desorb from coal beds near the outcrop. The desorbed gas could then migrate buoyantly updip to the outcrop and seep. The details of this potential process are not well understood at this time.

Heffern (1999), as quoted in the WYODAK Draft EIS (BLM, 1999c), compares the characteristics of the SJB of southwest Colorado and northwest New Mexico, with its coal fires, methane seeps, and high temperatures that have

killed vegetation, with the PRB to evaluate the potential for coal fires and methane migration or seepage within the PRB. Although some similarities exist between the two basins, there are significant differences.

- 1. Basin pressurization and regional groundwater flow the PRB is not an overpressured basin, as is the SJB. Groundwater flow in the PRB coal aquifer is downdip, toward the center of the basin (USGS, 1986b), rather than updip toward the outcrop.
- 2. Recharge from clinker Unlike the SJB where there is little groundwater recharge or clinker at the coal outcrop, extensive deposits of porous clinker occurring in the PRB near the coal mines trap rainfall and snowmelt and recharge the coal aquifers (USGS, 1988; Peacock, 1997).
- 3. Coal characteristics The bituminous coal in the SJB, while having less volatile matter, has developed better cleat and fractures than the sub-bituminous coal in the PRB. Due to its cleat, the SJB coal must be completely dewatered to achieve maximum production. The methane in the SJB is largely thermogenic, generated at depth from the high temperatures and pressures associated with burial. In the PRB, the methane is biogenic, and water is retained in the cell structure of the coal. In the PRB, overpumping of water from the coal could shut off methane flow if the cell structure collapses, rather than releasing methane (Selvig and Olde, 1953).
- 4. Basin structure In the SJB outcrop area, where methane seepage occurs, it is confined to a much smaller area. Therefore, methane seepage may be more concentrated in the SJB than in the PRB. The SJB also is more highly deformed than the PRB and contains more faults and fractures that could serve as conduits for methane migration. Aubrey, et al. (1998) also notes the lack of substantial caprock in the SJB that would limit the flow of groundwater or methane migration.
- 5. Experience in existing mines Mine fires are common in piles of coal fines and along the highwall in PRB mines, and are regularly extinguished. Since CBM development began, mine inspectors have not noted a significant increase or decrease in the number of fires in coal pits located east of the Marquiss and Lighthouse CBM projects where, to date, groundwater drawdown due to CBM development has been greatest. Moreover, the frequency of coal fires in these pits is similar to that for coal pits located some distance from CBM development.

Methane seepage can occur naturally in the vicinity of near-surface coal seams (Glass et al., 1987 and Jones et al., 1987). The potential for methane migration within the PRB is not limited to areas containing near-surface coal seams or areas where CBM drawdown has occurred. Methane migration potentially could occur at widespread locations within the PRB, as methane can migrate long distances along naturally occurring joints or fractures in rocks. Whether methane migration occurs in the PRB and whether methane seepage could accelerate the natural process of coal combustion is an unresolved question.

GROUNDWATER BALANCE

Groundwater resources can be balanced against current groundwater production and projected CBM water production within watersheds of the PRB. Exhibit 27 represents a calculated estimate of the water resources that exist in the coal seams of the Montana portion of the PRB. The estimate utilizes the acres within each watershed that have known coal occurrences that could be utilized for CBM development from Exhibit 3. Each acreage figure is multiplied by an average coal thickness of 70 feet from USGS Prof. Paper 1625-A. This is a volume figure that can be used with a porosity estimate (2%) to derive a total in-place groundwater volume for each watershed. These figures add up to an estimated 249.73 billion cu ft of groundwater for the projected CBM area of the PRB. This total does not include the volume of all the coal seams in the PRB, instead only those coals in the CBM potential development area. This total does not include waters held in non-coal aquifers.

EXHIBIT 27 - TOTAL GROUNDWATER RESOURCES IN THE COAL SEAMS OF THE MONTANA PRB WATERSHEDS

Calculated estimate of the water resources that exist in the coal seams of the Montana PRB

WATERSHED	COALBED THICKNESS (feet)	AVERAGE POROSITY OF THE COALS	TOTAL ACRES OF WATERSHED	TOTAL GROUNDWATER RESOURCE OF WATERSHED (Billion cu ft)
Little Big Horn	70	0.02	87,000	5
Little Powder	70	0.02	29,500	2
Lower Bighorn	70	0.02	121,500	7.5
Lower Tongue	70	0.02	1,374,000	84
Lower Yellowstone-Sunday	70	0.02	687,500	42
Middle Po wder	70	0.02	368,500	22.5
Mizpah	70	0.02	24,000	1.5
Rosebud	70	0.02	81,4000	49.5
Upper Tongue	70	0.02	589,000	34
TOTAL			4,095,000	248

Exhibit 28 shows a calculation of the potential water production resulting from the maximum number of CBM wells (from the RFD) for each PRB watershed per year. The average water production rate was calculated from an exponential trend analysis and the details can be seen in Appendix A. The table illustrates that the watersheds with the greatest water production are those with the most wells, i.e. Lower Tongue River, Upper Tongue River and Rosebud. The total water production for all CBM wells in all the watersheds is 4.4 billion cu. ft. per year or approximately 1.75 percent of the water in the coal seems of the Montana PRB Watersheds.

EXHIBIT 28 - MAXIMUM POTENTIAL PRODUCED CBM WATER BY MONTANA PRB WATERSHEDS

Calculation of the potential water production resulting from the maximum number of CBM wells from the RFD full-field scenario for each PRB watershed per year.

WATERSHED	EFFECTIVE ACRES (Acres)	MAX POTENTIAL PRODUCING WELLS	AVERAGE WATER PRODUCTION RATE PER WELL (gpm)	MAX POTENTIAL PRODUCED CBM WATER PER YEAR (Billion cu ft)	MAX POTENTIAL PRODUCED CBM WATER PER YEAR IN GPM (cfs)
Little Big Horn	87,179	1,050	2.5	0.184	2620 (5.80)
Little Powder	29,605	278	2.5	0.049	697 (1.55)
Lower Bighorn	121,538	1,200	2.5	0.211	3000 (6.70)
Lower Tongue	1,374,159	5,183	2.5	0.910	12,950 (28.9)
Lower Yellowstone- Sunday	687,303	2,568	2.5	0.451	6400 (14.3)
Middle Powder	368,349	3,167	2.5	0.556	7,900 (17.5)
Mizpah	23,941	224	2.5	0.039	555 (1.25)
Rosebud	813951	5397	2.5	0.948	13,500 (30.0)
Upper Tongue	589009	5806	2.5	1.020	14,500 (32.3)
TOTAL	4,095,034	24,873	2.5	4.4	62,600 (140)

SURFACE WATER IMPACT FROM DISCHARGE

Impacts to surface water from discharge of CBM water can be severe depending upon the quality of the CBM water. Some watersheds may be able to absorb the discharged water while others are sensitive to large amounts of low-quality CBM water. Surface water quality in the watersheds is tabulated in Exhibit 29. Water quality data is from stream gauging points maintained by the USGS. These multi-year collections of water quality data illustrate changes within the stream from times of high run-off (typically June for the PRB) when the river is the highest and water is mostly the result of precipitation from spring rains and melting snow. During periods of high flow the streams and rivers contain higher quality water. The USGS data also contains data on base-flow conditions (typically winter in the PRB) when streams are at their lowest flow and water quality is the lowest since much of the water is recharge from alluvial and bedrock aquifers where groundwater is often of low quality. Water quality data consisting of stream flow and SAR is averaged for a number of USGS gauging points to give base-flow information as well as high-flow conditions. Some streams such as the Tongue River show strong contrast between high-flow and base-flow rates while Mizpah shows the high contrast in water quality (SAR) from base-flow to high-flow. In addition to surface water information, projected CBM water discharge data is also included for comparison; the quality of discharge water is estimated to be the same as produced water from the CX Ranch field, SAR = 47. It is likely however that some of the coal aquifers contain water that differs from the CX Ranch produced waters.

EXHIBIT 29 - SURFACE WATER QUALITY BY WATERSHEDS

Tabulation of surface water quality in the watersheds of the Montana portion of the PRB gathered from USGS

stream gauging points.

WATERSHED	MAX CBM WATER DISCHARGE (From Exhibit 28)		AVERAGE BASE- FLOW		AVERAGE High-Flow	
	RATE	SAR	RATE	SAR	RATE	SAR
Little Big Horn (near Wyola)			61.8 cfs	1.2	526 cfs	0.2
Little Big Horn (near Crow Agency)	5.8 cfs	47	123 cfs	NA	782 cfs	NA
Little Big Horn (near Hardin)			138 cfs	2.0	851 cfs	0.5
Little Yellowstone-Sunday (Myers)			4200 cfs	1.7	42,000 cfs	0.7
Little Yellowstone-Sunday (Hysham)	14.3 cfs	47	0.01 cfs	8.5	280 cfs	1.5
Little Yellowstone-Sunday (Colstrip)			0.6 cfs	4.5	65 cfs	1.5
Little Powder (near Broadus)	1.55 cfs	47	0.35 cfs	NA	69	NA
Lower Bighorn (near St Xavier)	6.70 cfs	47	1750 cfs	2.5	10,300 cfs	1.7
Lower Bighorn (near Big Horn)	0.70 cis		640 cfs	3.7	21,500 cfs	1.2
Mizpah (near Mizpah)	1.25 cfs	47	26 cfs	21.0	60.1 cfs	6.5
Middle Powder (near Moorhead)	17.5 cfs	47	153 cfs	5.2	1433 cfs	2.5
Middle Powder (near Broadus)	17.5 CIS	47	198 cfs	NA	1077 cfs	NA
Rosebud (at Reservation Boundary near Kirby)			1.78 cfs	0.8	15.7 cfs	0.6
Rosebud (near Colstrip)	30 cfs	47	7.5 cfs	1.5	56.5 cfs	1.1
Rosebud (at mouth near Rosebud)			9.02 cfs	3.7	77.0 cfs	1.6
Upper Tongue (at state line)			181	NA	1724 cfs	NA
Upper Tongue (at Tongue R. Dam near Decker)	32.3 cfs	47	175	1.1	1467 cfs	0.4
Lower Tongue (near Birney Day School)			185	1.4	1202 cfs	0.4
Lower Tongue (near Ashland)	28.9 cfs	47	206	NA	2073 cfs	NA
Lower Tongue (at Miles City)			194	2.4	1305 cfs	0.6
TOTAL	115.75 cfs	47				

Produced CBM water can have impacts on surface water if it is discharged directly to streams and rivers. In a highest impact scenario, all the water produced in the projected CBM wells would be discharged to the primary drainage in each watershed. The results of this scenario are tabulated in Exhibit 30. In this table, the CBM discharge rate and base flow are taken for each watershed (from Exhibit 28) and added together to give the resultant combined flow. If the worst-case scenario would develop – 100% of the CBM produced water would be discharged at the gauging point during the average base-flow conditions. The resultant SAR values are a weighted average of the maximum CBM discharge and the average base-flow. Again for this scenario water quality was assumed to match that of CX Ranch. The biggest impacts would be those streams with low flow volumes and low SAR values such as Rosebud (near Kirby) that have a substantial increase in flow from the CBM discharge waters. In the case of Rosebud (near Kirby) the SAR increases from 0.8 to 44.4 and has an increase in flow from 1.78 cfs to 31.78 cfs.

EXHIBIT 30 - WORST-CASE DISCHARGE SCENARIO – BY WATERSHED – USING CX RANCH WATER QUALITY

Highest impact scenario for Montana PRB as tabulated from CX Ranch quality water for primary drainage in each watershed.

WATERSHED	MAX CBM WATER DISCHARGE		AVERAGE BASE- FLOW		RESULTANT FLOW: DISCHARGE + BASE- FLOW	
	RATE	SAR	RATE	SAR	TOTAL VOLUME	SAR
Little Big Horn (Near Wyola)			61.8 cfs	1.2	67.6 cfs	5.1
Little Big Horn (near Crow Agency)	5.8 cfs	47	123 cfs	NA	128.8 cfs	NA
Little Big Horn (near Hardin)			138 cfs	2.0	144.8 cfs	3.8
Little Yellowstone-Sunday (Myers)			4200 cfs	1.7	4214.3 cfs	1.9
Little Yellowstone-Sunday (Hysham)	14.3	47	0.01 cfs	8.5	14.31 cfs	47
Little Yellowstone-Sunday (Colstrip)			0.6 cfs	4.5	14.9 cfs	45
Little Powder (near Broadus)	1.55 cfs	47	0.35 cfs	NA	1.90 cfs	NA
Lower Bighorn (near St Xavier)	6.70 cfs	47	1750 cfs	2.5	1756.7 cfs	2.7
Lower Bighorn (near Big Horn)	0.70 CIS		640 cfs	3.7	646.7 cfs	4.1
Mizpah (near Mizpah)	1.25 cfs	47	26 cfs	21.0	28.25 cfs	21.4
Middle Powder (near Moorhead)	17.5 cfs	47	153 cfs	5.2	179.5 cfs	6.1
Middle Powder (near Broadus)	17.5 CIS	47	198 cfs	NA	224.5 cfs	NA
Rosebud (at Reservation Boundary near Kirby)			1.78 cfs	0.8	31.78 cfs	44.4
Rosebud (near Colstrip)	30 cfs	47	7.5 cfs	1.5	37.5 cfs	37.9
Rosebud (at mouth near Rosebud)			9.02 cfs	3.7	39.02 cfs	37
Upper Tongue (at state line)			181 cfs	NA	213.3 cfs	NA
Upper Tongue (at Tongue R. Dam near Decker)	32.3 cfs	47	175 cfs	1.1	207.3 cfs	8.25
Lower Tongue (near Birney Day School)			185 cfs	1.4	213.9 cfs	7.6
Lower Tongue (near Ashland)	28.9 cfs	47	206 cfs	NA	234.9 cfs	NA
Lower Tongue (at Miles City)			194 cfs	2.4	222.9 cfs	7.1

Except for the Little Big Horn and the Mizpah watersheds, the worst-case discharge would have unacceptable impacts on stream conditions. For both the Little Big Horn and Mizpah, the number of wells is expected to be so small, that discharge volumes are also expected to be small and dilution will be sufficient to avoid any significant degradation to water in terms of SAR. Other streams and rivers cannot withstand the maximum discharge of CBM water; the calculated resultant water would be unusable for irrigation. This statement is based upon the maximum number of CBM wells as computed by the RFD and the potential CBM map as well as the assumption that produced

water will be the same quality as CX Ranch water. If CBM produced water is less sodic than the CX Ranch water and closer to river water in quality, watersheds will be able to accept more CBM discharge. As discharge waters increase in volume, however, there is the potential to impact riparian areas via increased erosion and sediment transport. Exhibit 31 casts watershed flow rates against worst-case discharge rates at each potential discharge point. Increases caused by discharge range from approximately 0.1% if all 5,183 CBM wells discharge into the Lower Tongue near Ashland, MT up to 191% if all 1250 CBM wells discharge into the Rosebud near Kirby, MT. For the former, little erosion would be expected while for the latter, significant impact could be expected if riparian areas were prone to erosion.

EXHIBIT 31 - DISCHARGE VOLUMES AND HIGH-FLOW VOLUMES BY WATERSHEDS

Comparison of watershed flow rates to worst-case discharge rates at each potential discharge point.

WATERSHED	MAXIMUM CBM WATER DISCHARGE RATE	AVERAGE HIGH-FLOW RATE
Little Big Horn (Near Wyola)		526 cfs
Little Big Horn (near Crow Agency)	5.8 cfs	782 cfs
Little Big Horn (near Hardin)		851 cfs
Mizpah (near Mizpah)	1.25 cfs	60.1 cfs
Middle Powder (near Moorhead)	17.5 -f-	1433 cfs
Middle Powder (near Broadus)	17.5 cfs	1077 cfs
Rosebud (at Reservation Boundary near Kirby)		15.7 cfs
Rosebud (near Colstrip)	30 cfs	56.5 cfs
Rosebud (at mouth near Rosebud)		77.0 cfs
Upper Tongue (at state line)	20.2	1724 cfs
Upper Tongue (at Tongue R. Dam near Decker)	32.3 cfs	1467 cfs
Lower Tongue (near Birney Day School)		1202 cfs
Lower Tongue (near Ashland)	28.9 cfs	2073 cfs
Lower Tongue (at Miles City)		1305 cfs

CHAPTER 6 - MITIGATION OF IMPACTS TO WATER RESOURCES

Impacts to water resources can be reduced through the use of mitigation technologies. Mitigation may include project-scale permitting, protection of water rights, produced water management, and monitoring techniques.

MITIGATION

CBM production in the Montana PRB will certainly impact groundwater. Impacts to groundwater resources may however be mitigated through the use of water well agreements, limits placed on discharge and monitoring programs. Furthermore, a predictive model may be helpful as an approximation of future impacts. Groundwater rights will be protected through the use of spring/water well mitigation agreements and an approved monitoring plan to aid in the identification of potentially significant drawdown impacts. Surface water resources can be protected by limiting discharge through alternative management techniques.

Project planning will include protection of adjacent water rights and CBM rights through mitigation agreements and monitoring. Administration of CBM projects is the jurisdiction of the MBOGC with guidance from the MDNRC and the CBM Technical Advisory Committee. A monitoring plan will be required that may involve dedicated monitoring wells or systematic gauging of private water wells.

WATER MITIGATION AGREEMENTS

Water rights and mitigation agreements can be used to protect groundwater wells and springs. Both the MDNRC and the MBOGC advocate the use of agreements in areas surrounding CBM development as a way of protecting surrounding ranchers and farmers from damage from the inevitable drawdown. Water well mitigation agreements will be the cornerstones of CBM development in Montana. The contract simplifies relief for the aggrieved party (usually the landowner) to file claims without need for counsel. The contract further allows the operator to proceed with aquifer pump-down that is necessary for CBM development. If and when groundwater supplies are impacted, the operator will be required to deliver the same quality of water as that being impacted. The operator can then choose the water replacement option that bests suits his operating plan. Water well and spring mitigation agreements required by the MDNRC are listed in Appendix E and requirements of the MBOGC are described in Appendix F. Currently, CBM operators are required to offer mitigation agreements to residents within at least one-half mile of the edge of development. If any of these wells or springs are impacted, then agreements will be offered to land owners one-half mile beyond.

WATER RIGHTS

Water rights in Montana are guided by the prior appropriation doctrine, that is, first in time is first in right. A person's right to use a specific quantity of water depends on when the use of water began. The first person to use water from a source established the first right; the second person could establish a right to the water that was left, and so on. During dry years, the person with the first right has the first chance to use the available water to fulfill their right. The holder of the second right has the next chance. Water users are limited to the amount of water that can be beneficially used. Water rights in Montana are managed by three entities: the Department of Natural Resources and Conservation (DNRC), the Montana Water Court, and the district courts. DNRC administers the portions of the Montana Water Use Act that relates to water uses after June 30, 1973. DNRC trains water commissioners and teaches water-measuring techniques. DNRC also provides technical information and assistance to the Water Court, which is responsible for adjudicating water rights that existed before July 1, 1973. The Water Court decides any legal issues certified to it by DNRC that may arise in connection with permit or change applications, or in disputes filed in the district courts. The district courts can issue injunctive relief while it certifies water right issues to the Water Court for decision. DNRC maintains a central records system for all permits, changes, and certificates issued after June 30, 1973, and for all existing water rights filed as part of the statewide adjudication.

An individual or company does not need to apply for a permit to develop a well or a groundwater spring with an anticipated use of 35 gallons per minute or less, not to exceed 10 acre-feet per year. A person must have possessory interests in the property where the water right is put to a beneficial use or written notification 30 days prior to the

intent to appropriate groundwater. Also, a person must have exclusive property rights in the groundwater development works or written consent from the person with the property rights. Upon approval of the application, a Certificate of Water Right will then be issued to the owner for the specified use. Anyone anticipating to use more than 35 gallons per minute or 10 acre-feet per year of groundwater is required to obtain a Permit to Appropriate Water before any development begins or water is used. A permit may be required to appropriate groundwater in an area designated as a controlled groundwater area.

Specific to CBM development in the PRB, the Montana Department of Natural Resources issued a Final Order: "In the Matter of the Designation of the Powder River Basin Controlled Groundwater Area". The order appears as Appendix E at the end of this Technical Report. The order establishes that a CBM well does not require a MDNR Permit to appropriate water but the order sets out requirements for CBM wells and developments.

PRODUCED WATER MANAGEMENT

CBM water production will vary considerably in volume and quality and must be effectively managed during development. As has been seen in the CX Ranch field, water production rates can be expected to fall during the life of a new CBM field but the applicability of this data to other producing areas of the PRB is unknown. Produced water regulations must allow management alternatives so that costs will be kept low to promote wide CBM development. On the other hand, water management options must protect the full range of environmental resources. The choice of alternatives can depend on economics, regulatory burden, produced water quality, and local geographic conditions. The following are typical produced water management alternatives that are used in other CBM basins and in conventional oil and gas production:

- Discharge to impoundments: As is done in parts of the PRB in Wyoming, produced water can be discharged directly to ponds and tanks. In Montana these ponds require MBOGC permits and if the water is in excess of 15,000 mg/l TDS the pond or impoundment must be lined with an impermeable liner (ARM 36.22.1227). Such discharges will require a general produced water discharge MPDES permit from the MDEQ (ARM 17.30.1341).
- Discharge to surface water. Produced water can be discharged to waters of the state with an appropriate permit from the MDEQ. New discharges are subject to Non-degradation Rules (ARM 17.30.700). These rules prohibit increases in the discharge of toxic and deleterious materials to state waters, unless it is affirmatively demonstrated to the MDEQ that a change is justifiable as a result of necessary economic or social development and will not preclude present and anticipated use of these waters. Discharge rates will be calculated on the basis of the quality of the produced water and quantity and quality of the receiving water
- Disposal to shallow aquifers. It is possible to dispose of produced CBM water into shallow, drinking water aquifers. For example, produced water could be pipelined to a nearby area where coal aquifers do not produce methane and are not connected to productive coal seams. The produced water could be so injected with the required permit from the US EPA Region 8. Injection wells would be described as Class V aquifer recharge wells permitted under 40 CFR 146 Subpart F. If the injectate (CBM water) exceeds primary drinking water standards, the permit may require an aquifer exemption petition to the EPA. Shallow injection has the advantage of preserving the CBM water resource at the same time that surface waters and surface soil is protected.
- Disposal into deep zones. Operators can inject CBM produced water into deeper reservoirs that are not classified as USDWs. Montana contains many of these reservoirs scattered across the state. The reservoirs' ability to accept large volumes of injected water and their depths are highly variable. Deep injection requires a permit from the MOBGC and could require a permit from the US EPA if Indian Tribal Land is involved. Deep injection can be limited by economics if suitable injection zones are too deep or cannot accept sufficient fluid relative to the volume of water produced by CBM development. Deep injection has the advantage of protecting surface water resources but the CBM water resource is lost. In addition, injection wells are dedicated facilities that can be extremely expensive to drill and operate.
- Industrial beneficial uses. Oil and gas and CBM development will require large quantities of water during drilling, completion, and testing. Coal mining can require large volumes of water for dust control, slurry mining, and slurry pipelining. Other industries such as manufacturing and meat processing may have uses that are compatible with CBM produced water.

- Agricultural beneficial uses. Montana ranchers and farmers require large volumes of water to irrigate crops and water livestock. Irrigation uses have a narrow range of acceptable water quality depending upon soil type and crop selection but some reported coal aquifers contain suitable water. Soils and crops have a particular sensitivity to sodium and its concentration relative to calcium and magnesium in the water. Livestock have a somewhat wider range of quality acceptance depending upon the types of animal being raised. Livestock also has sensitivity to other contaminants in the water. Within the planning period, agricultural uses of the produced water from CBM operations may become more prevalent across the state.
- Pre-Disposal treatment. Produced water can be treated prior to being discharged or disposed. Treatment such as reverse osmosis (RO) can be targeted at a single ion such as sodium, rendering the processed water more compatible for a beneficial use. Skid-mounted RO units can be installed near "pod" manifolds or at single high-delivery wells. RO units can be powered by natural gas or electricity including wind turbines. Economics will vary on a site by site basis.

CHAPTER 7 - CONCLUSIONS

Analysis of the key potential impacts to water resources in the CBM emphasis area and especially the Montana portion of the PRB leads to the following conclusions. These conclusions are aimed toward water resource issues raised in public scoping comments as part of this EIS process.

- 1. **Water Conservation:** CBM production is calculated to drawdown the water level on coal beds being exploited; natural gas cannot be produced unless the water level is effectively pumped down. If these coal beds are also used for water in nearby wells, water levels in the nearby water wells may also be drawn down. These impacts are part of the CBM production process. The impacts will likely be variable in magnitude and geographic extent.
- 2. **Groundwater Quality and Quantity:** Many water wells in the Montana portion of the PRB are completed in shallow alluvial aquifers and deeper Cretaceous sands. These aquifers are likely isolated from impact by CBM development. Local conditions could, however, show the presence of physical connection between these sands and the CBM reservoirs.
- 3. **Wastewater Disposal and Discharge**: Quality of CBM water is extremely variable and must be considered before discharge is permitted. Current production carries water with only limited beneficial use that must be managed so as to fully protect surface water and soil resources. Some coal beds in the Montana portion of the PRB, however, contain high quality water that can be used for animal husbandry or irrigation. Water management alternatives will be driven by produced water quality.
- 4. Water Rights: Water well and spring mitigation agreements will aid responsible CBM development while protecting water rights. As coal aquifer water levels are drawn down, methane may be liberated. This could happen at local water wells and monitoring wells adjacent to CBM production. Mitigation may be necessary depending on local conditions. However, determination of the adequacy of areas requiring mitigation agreements will likely require an active groundwater monitoring program that would need to include field reconnaissance to assess potential impacts to natural springs and other vulnerable resources.
- 5. Water Resources Impacts: The groundwater volume in the coals of the Powder River Basin is sufficiently large that even full-field CBM development will likely not exhaust the resource. However, areas with substantial CBM development could experience adverse impacts that could include water wells becoming dry, reduced flow from springs, seeps from unlined impoundments, impacts to soils irrigated with water produced from CBM wells (Soils Technical Report), and degradation of surface water.

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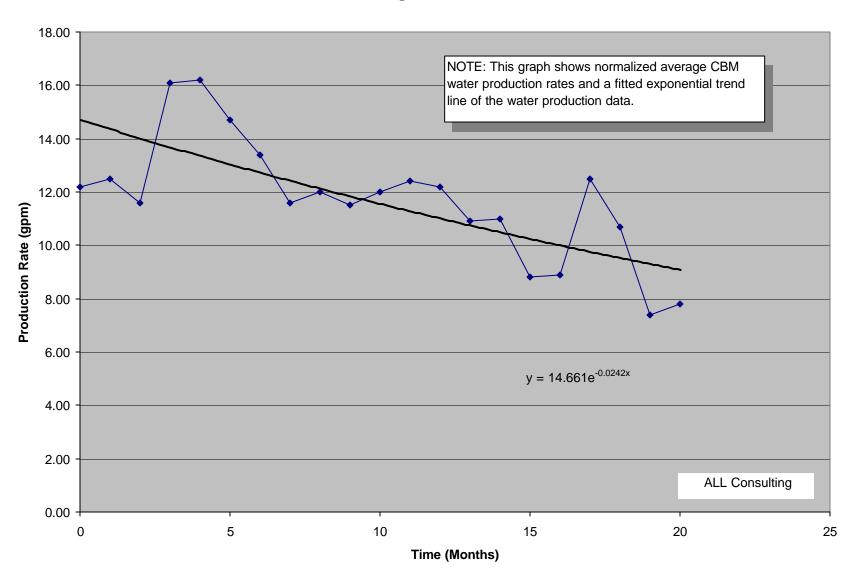
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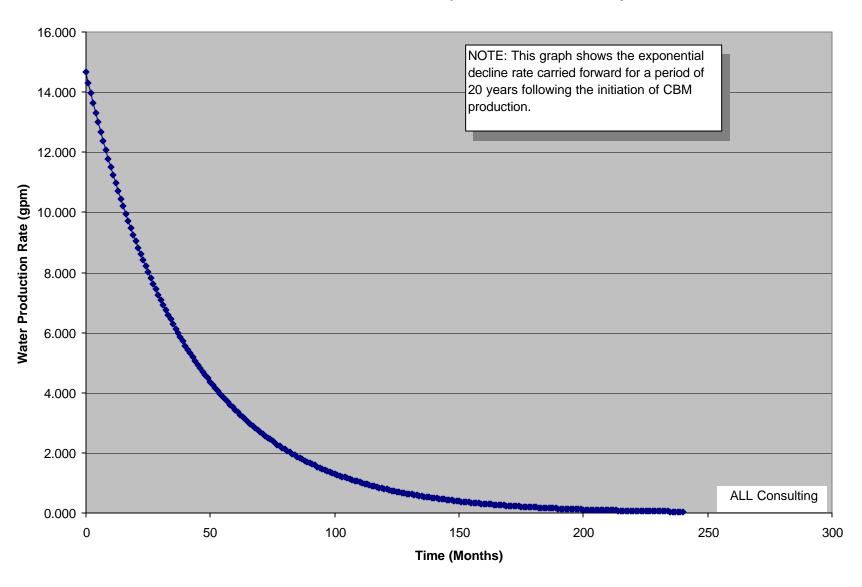
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APPENDIX A CX RANCH WATER PRODUCTION DECLINE ANALYS IS

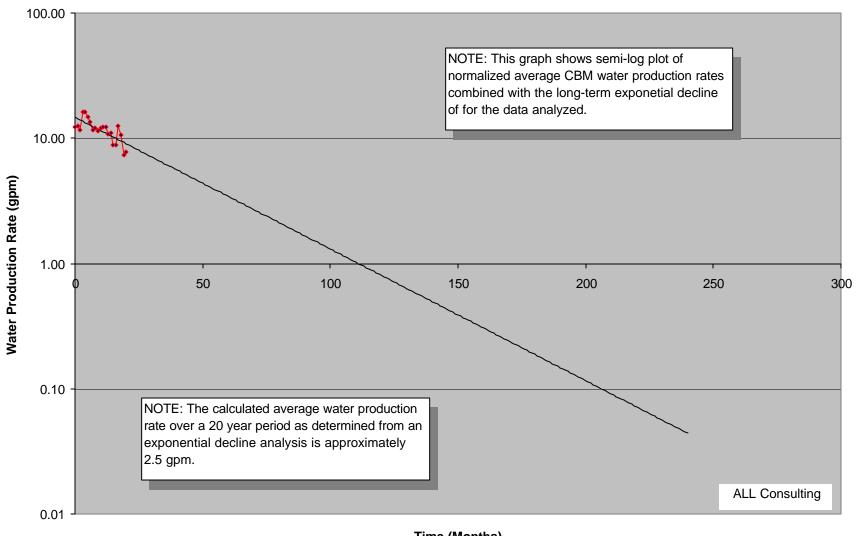
Normalized Average CBM Water Production Rates



CBM Water Production Exponential Decline Analysis



CBM Combined Water Production and Decline Analysis



Time (Months)

Months	Poto	Dooling
_	Rate 12.20	Decline 14.661
0 1		14.310
	12.50	
2	11.60	13.968
3	16.10	13.634
4	16.20	13.308
5	14.70	12.990
6	13.40	12.680
7	11.60	12.376
8	12.00	12.080
9	11.50	11.792
10	12.00	11.510
11	12.40	11.235
12	12.20	10.966
13	10.90	10.704
14	11.00	10.448
15	8.80	10.198
16	8.90	9.954
17	12.50	9.716
18	10.70	9.484
19	7.40	9.257
20	7.80	9.036
21		8.820
22		8.609
23		8.403
24		8.202
25		8.006
26		7.815
27		7.628
28		7.445
29		7.267
30		7.094
31		6.924
32		6.758
33		6.597
34		6.439
35		6.285
36		6.135
37		5.988
38		5.845
39		5.705
40		5.569
41		5.436
42		5.306
43		5.179
44		5.055
45		4.934
46		4.816
47		4.701
48		4.589
40		4.509

Mantha	Data	Dealine
Months	Rate	Decline 4.479
49 50		
50		4.372
51 50		4.267
52		4.165
53		4.066
54		3.969
55		3.874
56		3.781
57		3.691
58		3.602
59		3.516
60		3.432
61		3.350
62		3.270
63		3.192
64		3.116
65		3.041
66		2.968
67		2.897
68		2.828
69		2.760
70		2.694
71		2.630
72		2.567
73		2.506
74		2.446
75		2.387
76		2.330
77		2.275
78		2.220
79		2.167
80		2.115
81		2.065
82		2.015
83		1.967
84		1.920
85		1.874
86		1.829
87		1.786
88		1.743
89		1.701
90		1.661
90		1.621
92		1.582
93		1.544
94		1.507
95		1.471
96		1.436
97		1.402

B	D. (.	D. H.
Months	Rate	Decline
98		1.368
99		1.336
100		1.304
101		1.273
102		1.242 1.212
103		1.212
104		1.163
105		
106 107		1.127 1.101
107		1.074
108		1.049
110		1.023
111		0.999
112		0.999
113		0.975
114		0.932
115		0.929
116		0.885
117		0.864
118		0.843
119		0.823
120		0.823
120		0.803
121		0.764
123		0.766
123		0.729
125		0.729
126		0.695
127		0.678
128		0.662
129		0.646
130		0.631
131		0.616
132		0.601
133		0.587
134		0.573
135		0.559
136		0.546
137		0.532
138		0.520
139		0.507
140		0.495
141		0.483
142		0.472
143		0.461
144		0.450
145		0.439
146		0.428
0		3.120

B#	D . 1 .	D I'
Months	Rate	Decline
147		0.418
148		0.408
149		0.398
150		0.389
151		0.379
152		0.370
153		0.362
154 155		0.353
155 156		0.344 0.336
156		0.328
157		0.326
159		0.320
160		0.313
161		0.303
162		0.298
		0.284
163 164		0.264
165		0.277
166		0.270
167		0.258
167		0.258
169		0.245
170		0.240
170		0.234
171		0.234
172		0.223
173		0.223
175		0.217
175		0.217
177		0.202
178		0.197
179		0.193
180		0.188
181		0.184
182		0.179
183		0.175
184		0.171
185		0.167
186		0.163
187		0.159
188		0.155
189		0.151
190		0.148
191		0.144
192		0.141
193		0.137
194		0.134
195		0.131
.00		3.101

Months	Doto	Decline
	Rate	
196		0.128
197		0.125
198		0.122
199		0.119
200		0.116
201		0.113
202		0.110
203		0.108
204		0.105
205		0.103
206		0.100
207		0.098
208		0.096
209		0.093
210		0.091
211		0.089
212		0.087
213		0.085
214		0.083
214		0.083
216		0.079
217		0.079
217		0.077
219		0.073
220		0.071
221		0.070
222		0.068
223		0.066
224		0.065
225		0.063
226		0.062
227		0.060
228		0.059
229		0.057
230		0.056
231		0.055
231		0.053
233		0.052
234		0.051
235		0.050
236		0.049
237		0.047
238		0.046
239		0.045
240		0.044



APPENDIX B

WATER QUALITY DATA FROM THE ROSEBUD MINE, COLSTRIP, ROSEBUD COUNTY, ${\color{blue} \mathbf{MONTANA}}$

Appendix B - Rosebud Mine Area Groundwater Quality Data From MDEQ Files

	Number											
	of							Fe	Mn			
Aquifer	Samples	Calc. TDS	SAR	Ca	Mg	Na	K	Diss.	Diss.	Al Diss.	Bicarb.	CO3
				780 to							54 to	
		75	0.29 to 20	0	4 to 2140		0 to 38		0 to 12.6		1420	0 to 12
		75 to 14,142	(778	(780	• •	• ,	• .	• .	• .	mg/l (757	• •	• ,
		(610 samples,	•						•	•		•
Allen de um	1071	median=2647		median=								
Alluvium	1071	mg/l)	1.8)	220 mg/I)	273 mg/l)	174 mg/l)	6.0 mg/i)	0 mg/l)	0.6 mg/i)	0.0 mg/l)	535 mg/I)	0.0 mg/l)
								0 to				
					3.0 to	1.0 to		37.10	0 to 168		22.0 to	
		46 to 10,392	0.07 to 38	6 to 857	1585	965 mg/l	0 to 27.0	mg/l (585	mg/l (516	0 to 6.2	1098	0 to 365
		mg/l (482	(581	mg/l (587	mg/l (587	(588	mg/l (588	samples,	samples,	mg/l (459	mg/l (584	mg/l (559
		samples,	samples,	samples,	samples,	samples,	samples,	median=	median=			•
		median=1800	median=	median=				0.06	0.10		median=	
McKay Coal	733	mg/l)	2.04)	153 mg/l)	120 mg/l)	166 mg/l)	5.0 mg/l)	mg/l)	mg/l)	0.0 mg/l)	516 mg/l)	0.0 mg/l)
						0.33 to						
						890 mg/l	0 to	0 to 126	0 to 5.70		25 to	
		218 to 6269	0 to 20	29 to 834	17 to 807	(522	41mg/l		mg/l (467	0 to 7.8	1218	0 to 33.0
		mg/l (446	(520	mg/l (524	mg/l (524	samples,	(522	• •	• •	mg/l (361	mg/l (521	mg/l (515
		samples,	samples,	samples,	samples,	median=	samples,	median=	median=	samples,	samples,	samples,
		median=1311	median=	median=	median=	97.0	median=	0.04	0.16	median=	median=	median=
Rosebud Coal	632	mg/l)	1.34)	139 mg/l)	138 mg/l)	mg/l)	5.0 mg/)	mg/l)	mg/l)	0.0 mg/l)	546 mg/l)	0.0 mg/l)
				2.0 to	1.0 to 611	7.0 to		0 to 5.60	0 to 1 03		142 to	
		456 to 6722	0.12 to		mg/l (229	1030	0 to 3/1 0	mg/l (224		0 to 2 20	1150	0 to 18.0
		mg/l (166	55.8 (229	(229	J (• .	• .	mg/l (221		
		samples,	`	samples,		• ,	• .		•	• •	• •	• ,
Sub-McKay		median=1654	median=		82.0	median=	•	0.03	0.06	•	median=	•
Coal	294	mg/l)	6.06)	96 mg/l)	mg/l)	328 mg/l)		mg/l)	mg/l)		498 mg/l)	
			,			3, .)	- '- ''- ''			/ /		

Appendix B - Rosebud Mine Area Groundwater Quality Data From MDEQ Files

			Nitrite,		As		Cd	Cr	Cu	Pb	Hg	Mb	
Aquifer	CI	SO4	Nitrate	F	Diss.	В	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Ni Diss.
		10 to											
		9330		0 to 3.10									
				mg/l (777									0 to 0.10
	• .			samples,		•	• •	• •	• •	• .	• •	0 40 0 70 71/1	mg/l (20
	median=	median= 1600	0.22	0.26	0.01	0.40		•	median=	•	•	0 to 0 mg/l (9	samples, median=
Alluvium	20 mg/l)	mg/l)	mg/l)	mg/l)	mg/l)	mg/l)			0.0 mg/l)			samples)	0.0 mg/l)
	3 ,	5. /	J. 7	J. ,	J. 7	0 to	3. 7	3.7	3. 7	3. ,	3. 7	1 7	3 ,
			0 to 6 60	0 to 2.90	0 to 0.01	17.90							
	0 to 189	5 to 760		mg/l (584			0 to 0.03	0 to 0.08	0 to 0.14	0 to 0.28	0 to 0.002	0 to 0.04	0 to 0.10
			• .	•	• .	• •					mg/l (406		mg/l (63
	samples,	samples,	median=	median=	median=	median=	samples,	samples,	samples,	samples,	samples,	samples,	samples,
		median=	0.06	0.23	0.01	0.40						median=0.	
McKay Coal	7.0 mg/l)	935 mg/l)	mg/l)	mg/l)	mg/l)	mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	0 mg/l)	0.0 mg/l)
	0		0.040	0.4.0.40	0040	0. 447							0.4.000
	0 to 143 mg/l (521	30 to 4520		0 to 2.19 mg/l (521	0 to 0.10		0 to 0 01	0 to 0 12	0 to 0.66	0 to 0 10	0 to 0.0024		0 to 0.09
	• (O (samples,	• .	• ,					(327		mg/l (1023
	•	•		median=		•	• •	• •	• .	•	•		samples,
	7.10	median=	0.05	0.20	0.01	0.51		•	median=		•	0 (3	median=
Rosebud Coal	mg/l)	664 mg/l)	mg/l)	mg/l)	mg/l)	mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	0.0 mg/l	samples)	0.0 mg/l)
			0 to	0.04 to	0.01 to								
		25.6 to	29.93	5.0 mg/l	0.44 mg/l	0 to 1.40							
	0 to 81.0	4120	mg/l (227	(229	(24	mg/l (142				0 to 0.14			
	• .	• .		samples,		•	• •	0.0	5 (mg/l (224	(197		0.0 "
Cub Mal/air	•	•		median=				mg/l(9	•	samples,	•		0.0 mg/l
Sub-McKay Coal		median= 898 mg/l)	0.05 mg/l)	0.39 mg/l)	0.41 mg/l)	0.30 mg/l)	median= 0.0 mg/l)	samples	median=	median= 0.0 mg/l)		N. A.	(1 sample)
Odai	5.0 mg/l)	000 mg/1)	1119/1)	1119/1/	1119/1)	1119/1/	0.0 mg/l)	,	0.0 mg/l)	0.0 mg/l)	0.0 mg/l)	1 N. /\.	Jampie)

Appendix B - Rosebud Mine Area Groundwater Quality Data From MDEQ Files

		Va	Zn	Во			
Aquifer	Se	Diss.	Diss.	Diss.			
Alluvium	0 to 0.18 mg/l (681 samples, median= 0.0 mg/l)	0 to 1.00 mg/l (675 samples, median= 0.0 mg/l)	0 to 2.09 mg/l (753 samples, median= 0.03 mg/l)	0 to 31.6 mg/l (247 samples, median= 0.40 mg/l)			
McKay Coal	0 to 0.07 mg/l (401 samples, median= 0.0 mg/l)	0 to 1.00 mg/l (399 samples, median= 0.0 mg/l)	0 to 4.67 mg/l (543 samples, median= 0.10 mg/l)	0 to 4.0 mg/l (152 samples, median= 0.40 mg/l)			
Rosebud Coal	0 to 0.02 mg/l (317 samples, median= 0.0 mg/l)	0 to 1.21 mg/l (321 samples, median= 0.0 mg/l)	0 to 8.01 mg/l (500 samples, median= 0.06 mg/l)	0 to 4.60 mg/l (113 samples, median= 0.40 mg/l)			
Sub-McKay Coal	0 to 0.09 mg/l (197 samples, median= 0.0 mg/l)	0 to 0.10 mg/l (195 samples, median= 0.0 mg/l)	0 to 17.20 mg/l (224 samples, median= 0.08 mg/l)	0 to 2.0 mg/l (81 samples, median= 0.40 mg/l)			

APPEN FINAL ORDER PRB CONT ROLLED GROUNDWATER							
TIME STUDIES IN ROLLED STOCK WITH EACH							
APPENDIX C							
WATER QUALITY DATA FROM THE DECKER MINE AREA, BIG HORN COUNTY, MONTANA							

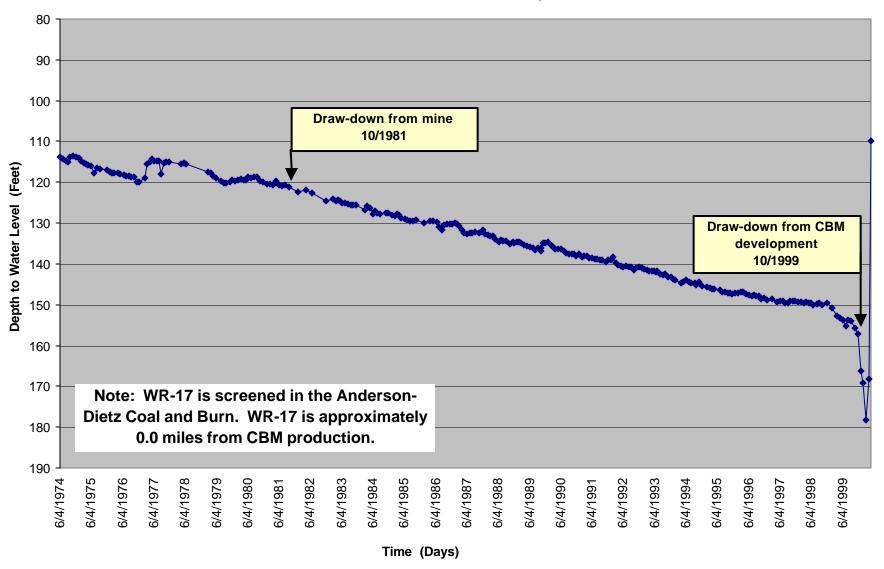
Appendix C - Decker Mine Area Water Quality Data From MDEQ

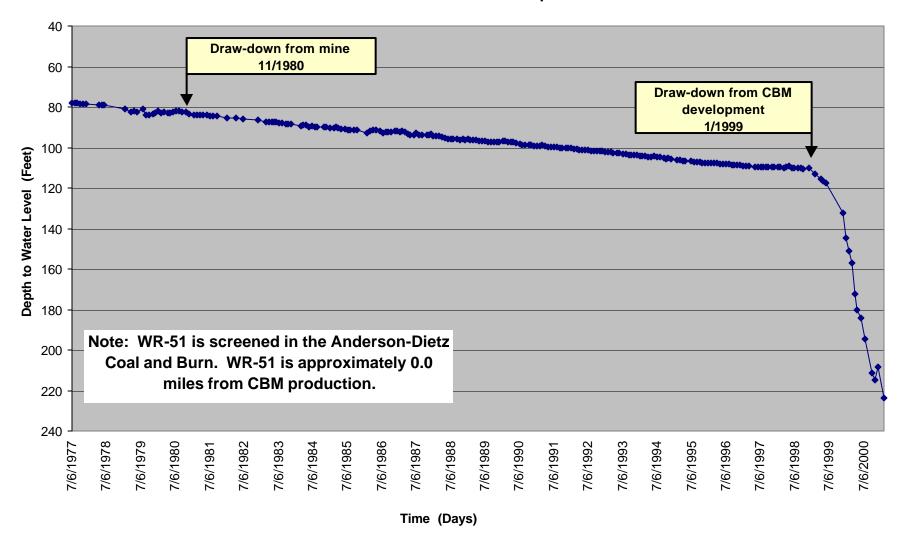
	Number													Diss.					
	of	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Diss.	Bicarb	Diss.	Diss.	Diss	Diss.	
Aquifer	Samples	ΑI	As	В	Ва	Ca	Cd	CI	CO3	Cr	Cu	F	Fe		Hg	K	Mg	Mn	
		0 to	0 to	0 to		158 to	0 to			0 to	0 to	0.2 to	0 to	522 to		4.2 to	165 to	0 to	
		0.15	0.002	1.03		269	0.005	16 to		0.06	0.01	6.11	0.49	635	0.0	23.6	263	0.19	
Alluvium	42	mg/l	mg/l	mg/l	0 mg/l	mg/l	mg/l	37 mg/l	0 mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
		0 to		0.0 to	0 to	1.6 to	0 to	6 to			0 to	0.49 to	0 to	394 to		1.0 to	0.35 to	0 to	
		16.8	0.0	0.85	0.06	20.0	.004	140	0 to 70	0 to .05	0.12	4.44	1.81	2010	0.0	37.8	13.0	0.47	
Anderson	82	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
			0 to	0 to	0 to	2 to	0 to		0 to	0 to	0 to	0.22 to	0 to	0 to	0 to		0 to		
		0 to 6.3	0.014	1.73	1.49	236	0.013	1.7 to	137	0.03	0.06	18	6.74	2360	0.003	0 to 25	454	0 to 1.8	3
Dietz	261	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	89 mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
				0 to	0 to		0 to		0 to		0 to	1.65 to	0 to	1189 to		3.7 to		0 to	
		0 to 1.2	0.0	0.73	1.4	3 to 36	0.003	3.3 to	240	0.0	0.02	5.14	0.78	2172	0.0	17.3	0 to 85	0.11	
Canyon	54	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	31 mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	

Appendix C - Decker Mine Area Water Quality Data From MDEQ

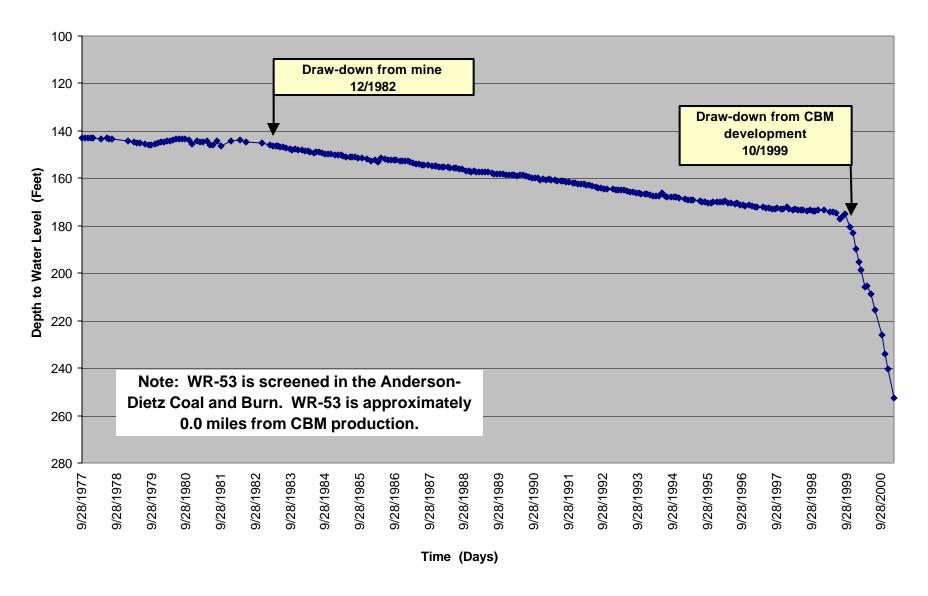
Aquifer	Diss Mo	Diss. Na	NH3	Diss. Ni	Nitrate + Nitrite	Diss. Pb	Diss. Se	Diss. SO4	Diss. Zn	SAR	TDS (dried)
	0 to	552 to	0 to	0 to	0.1 to		0 to	to	0 to		
	0.05	750	0.79	0.18	1.49	0.0	0.005	2552	1.36		3420 to
Alluvium	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	0.3 to 8	4340 mg/l
	0 to 0.05	145 to 1036	0 to 27.8	0 to 0.08	0 t 10.27	0 to 0.04	0 to 0.005	0 to 663	0 to 0.32		502 to 3400
Anderson	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	8 to 77	mg/l
Dietz	0 to 0.08 mg/l	44 to 987 mg/l	0 to 8.91 mg/l	0 to 0.15 mg/l	0 to 3.72 mg/l	0 to 0.02 mg/l	0 to 0.01 mg/l	0 to 3690 mg/l	0 to 1.04 mg/	1 to 131	430 to 6520 mg/l
Canyon	0 to 0.02 mg/l	451 to 863 mg/l	0 to 4.36 mg/l	0 to 0.04 mg/l	0 to 3.47 mg/l	0 to 0.01 mg/l	0.0 mg/l	0 to 672 mg/l	0 to 0.86 mg/l	14 to 72	1060 to 2860 mg/l

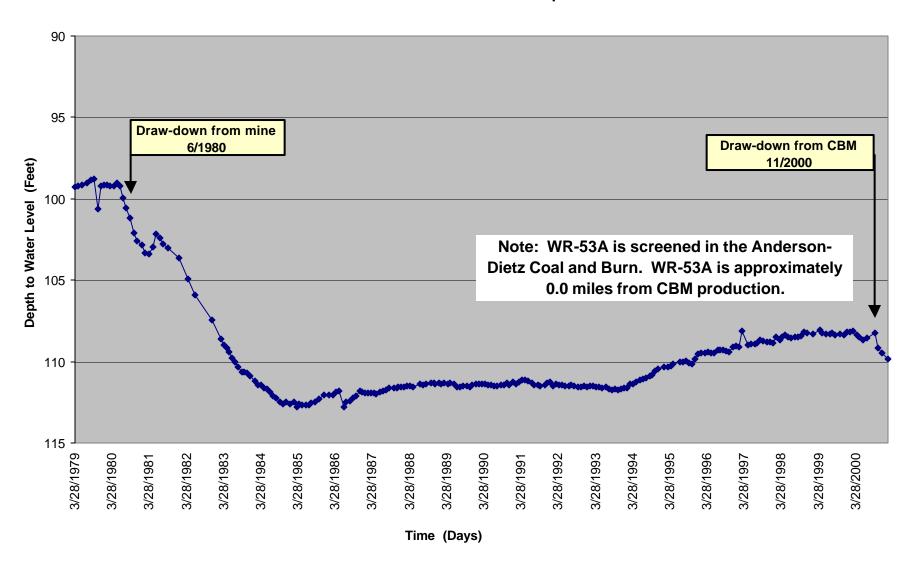
APPENDIX FINAL ORDER PRB CONT ROLLED GROUNDWATER AERA	
APPENDIX D	
SELECTED HYDROGRAPHS IN THE AREA OF CX RANCH, BIG HORN COUNTY, MONTANA	

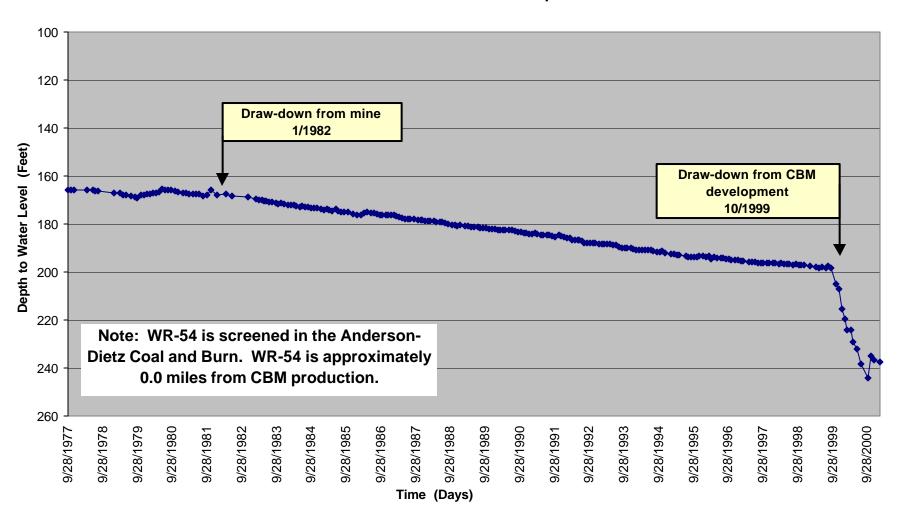


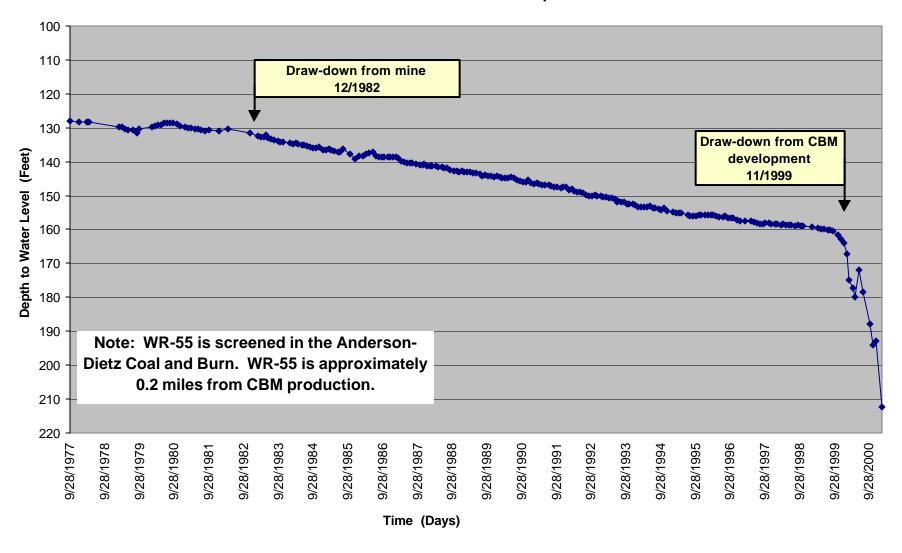


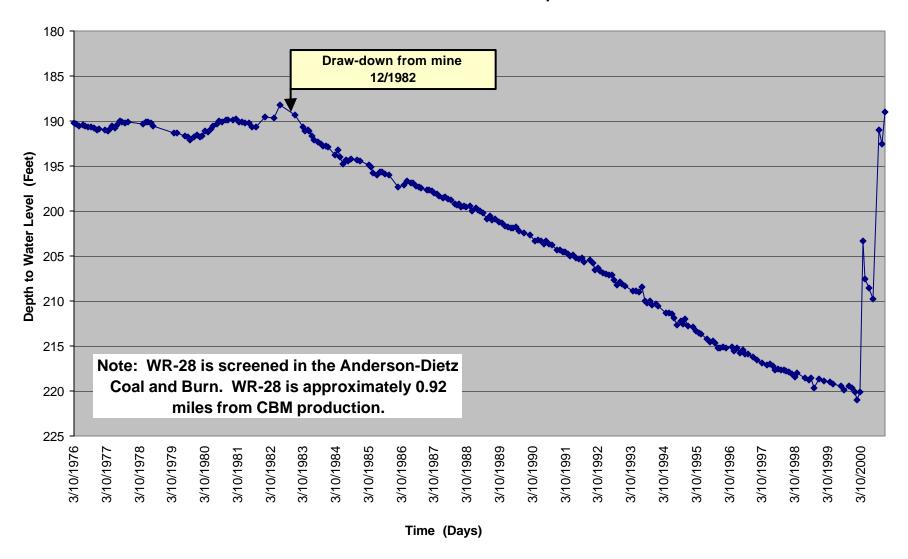
Hydrograph: Well #WR - 53

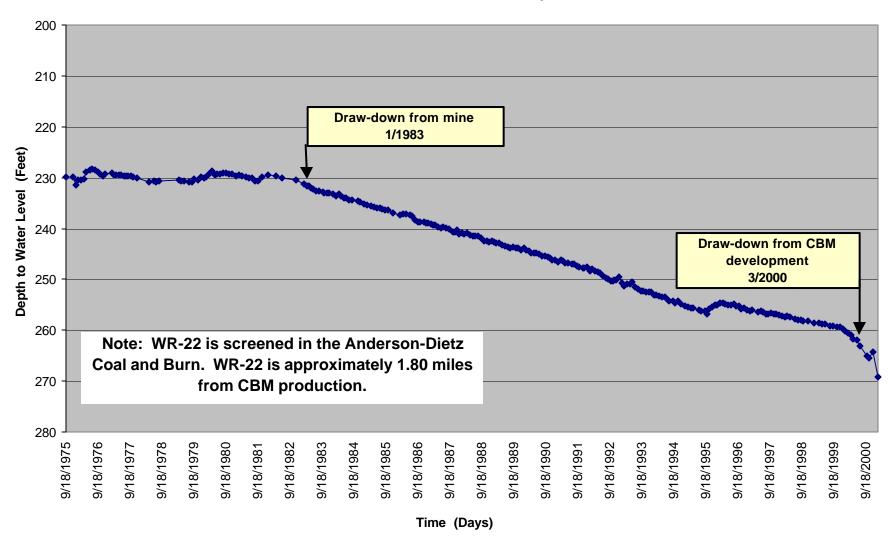


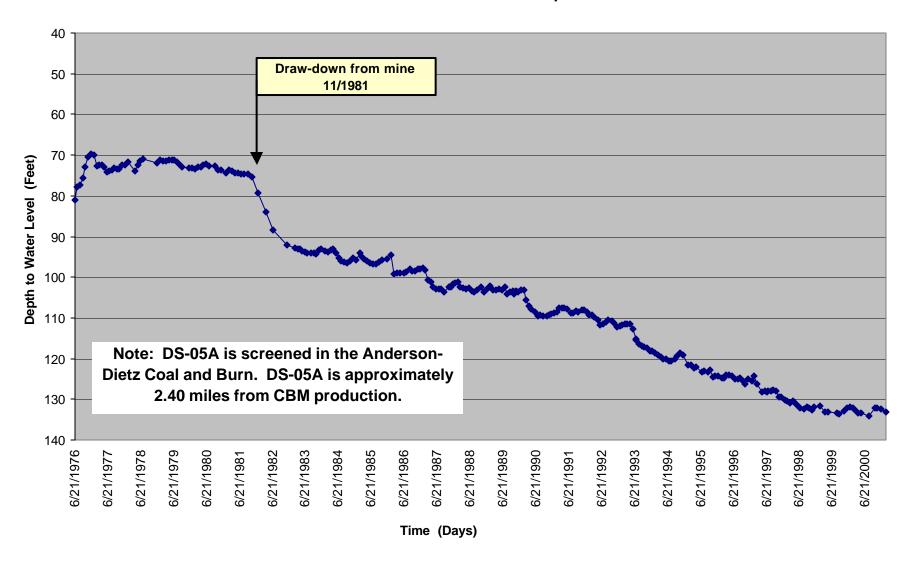


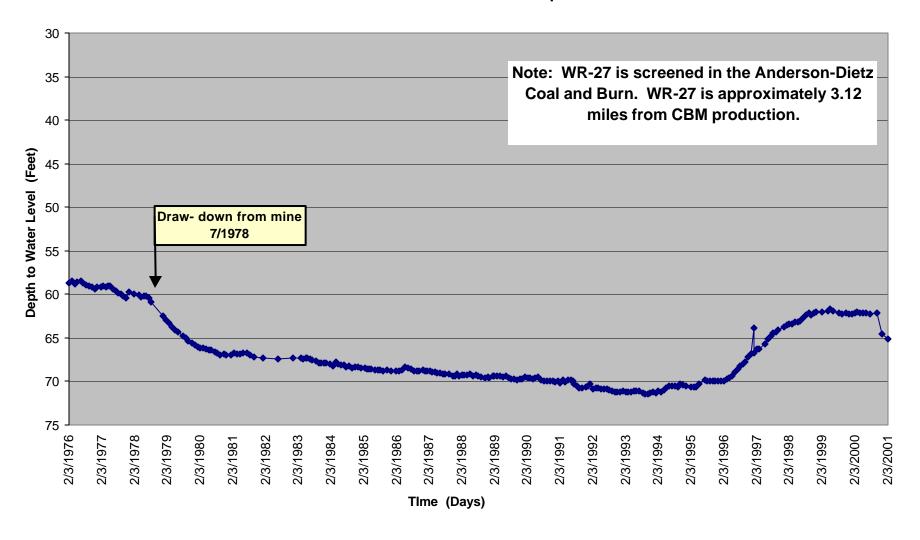


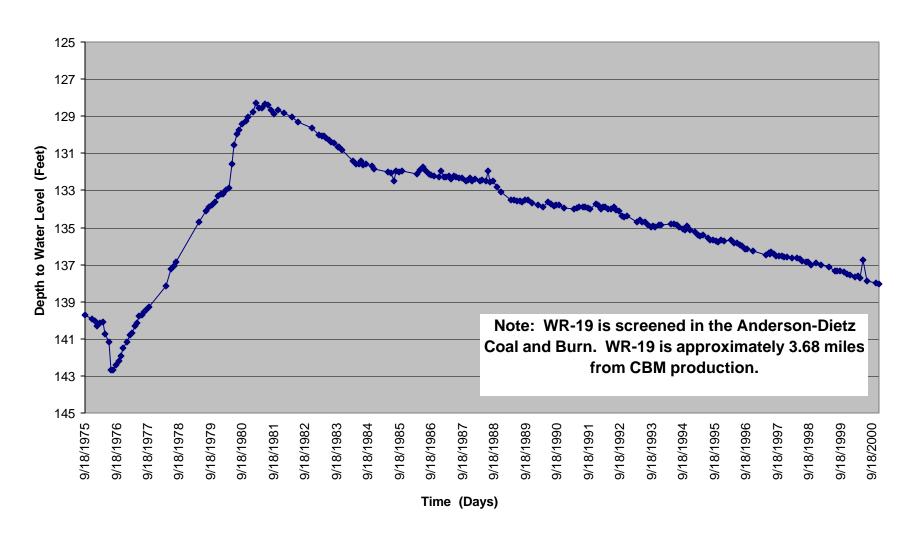


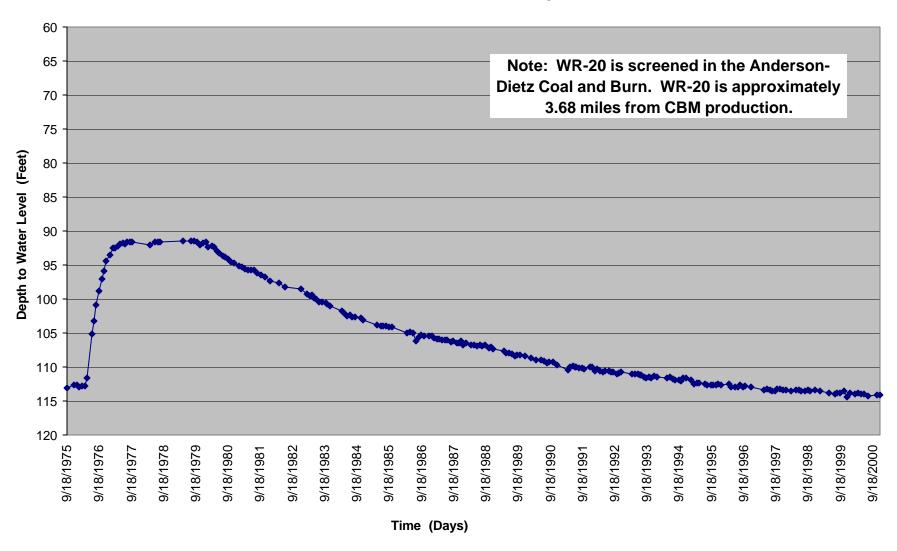


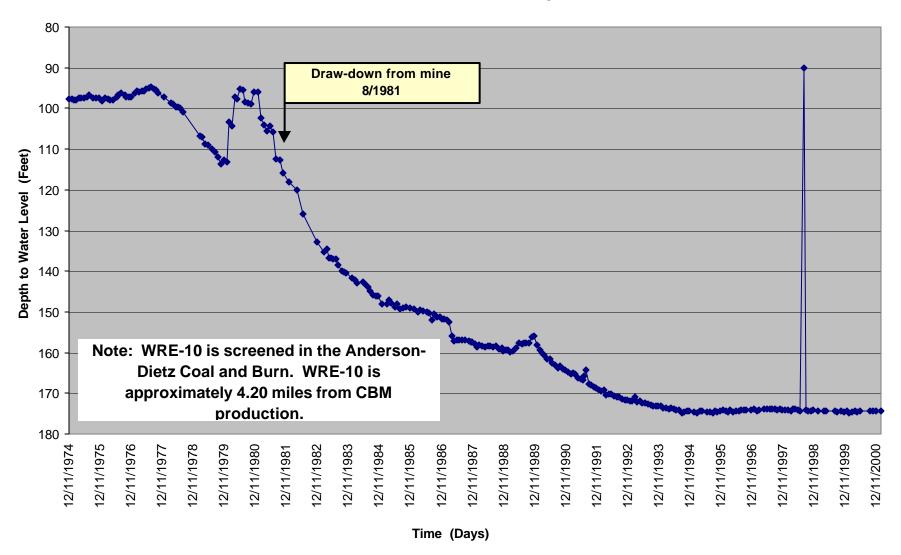












APPENDIX E

FINAL ORDER IN THE MATTER OF THE DESIGNATION OF THE POWDER RIVER BASIN CONTROLLED GROUNDWATER AREA

FINAL ORDER

IN THE MATTER OF THE DESIGNATION OF THE POWDER RIVER BASIN CONTROLLED GROUNDWATER AREA

BEFORE THE DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION OF THE STATE OF MONTANA

FINAL ORDER

IN THE MATTER OF THE DESIGNATION OF THE POWDER RIVER BASIN CONTROLLED GROUNDWATER AREA

Pursuant to the Montana Water Use Act, Mont. Code Ann. § 85-2-506, and after notice required by law, public hearings were held on September 22 and 23 in Lodge Grass, Colstrip, Miles City, and Broadus to consider the Montana Department of Natural Resources and Conservation's proposal to designate a controlled groundwater area for the Powder River Basin in anticipation of expected groundwater withdrawals associated with coal bed methane development in the area. Comments were accepted into the record at the hearings and written comments were accepted through October 8, 1999. Based on the information gathered by the Department, the input of other agencies, and the public comment received the Department has modified its proposed findings, conclusion, and order as will follow. The public comment is addressed in the Memorandum that appears at the end of this order.

FINDINGS OF FACT

- Coal bed methane extraction technology requires groundwater withdrawal to lower groundwater levels and reduce water pressures in the coal beds. Wells may be placed at regular intervals over large areas covering many square miles. The wells are pumped continuously with the specific intent of lowering water pressures in the coal bed. Lowering water pressures will lower water levels in the aquifer.
- 2. During coal bed methane development, water is removed only from coal aquifers. Other aquifers in an area in a coal bed methane development area may or may not be affected depending upon connections between aquifers.

- 3. Coal beds are important regional aquifers in water-scarce southeastern Montana. The coal aquifers are often the only practical source of fresh water for domestic, stock, and agricultural uses by the people in the area.
- 4. The complexities of geology and hydrogeology and the uncertainty about the extent and precise location of future coal bed methane development do not allow an accurate assessment of conflicts with existing and future beneficial water use. However, there is considerable data available showing significant effects on water levels in coal aquifers from extensive and continuous pumping of water from coal mines in the Decker area.
- 5. Since coal bed methane development is of limited duration, 20 to 30 years, in any particular field, and because the aquifer is not otherwise disturbed, water in the aquifer most likely will recover to its pre-development level. However, even if an aquifer were to recover rapidly after development, the long period of development could cause severe hardship to local water users. Moreover, interrelationships among aquifers along with future precipitation patterns could cause unpredictable results.
- 6. Assessment of localized effects of coal bed methane development on water availability would require compiling baseline data from existing wells, before methane gas development, along with data from test wells and coal bed methane production wells. Monitoring of water levels, water pressures and pumping rates during development would also be necessary to determine the effects.
- 7. The Department of Natural Resources and Conservation usually considers a one-half mile radius from any particular water well as the zone of possible influence from the well. When the Department receives an application for a water well the owners of all existing wells within that radius are notified. Available information does not justify an assumption that wells for coal bed methane development should be considered any different. However, neither does the information justify any assumption that wells or springs over a half a mile from coal bed methane development will not be affected. Baseline information should be gathered for any well within the general location of coal bed methane development so that the effects can be monitored.
- 8. Although withdrawing groundwater is integral to the coal bed methane extraction method, water is not a desired product of the operation, and must be disposed. Since the withdrawal of the water is not a use of the water per se, a water use permit from the DNRC is not required for withdrawing the water. Public authorities do not otherwise regulate the withdrawal of ground water in the area except as it relates to coal mining.
- 9. Water withdrawn during coal bed methane withdrawal may be suitable for use by local residents, agriculture, and business. Wells drilled for coal bed methane development could in some cases be developed as water sources for local residents, agriculture, and business.
- 10. Wells that are inadequately sealed present a hazard of contaminating water in one aquifer with contaminants from another aquifer or introducing methane into non-coal aquifers. The Board of Oil and Gas Conservation regulates well construction and enforces standards for sealing gas wells. These standards are in excess of the

- standards of sealing water wells enforced by the Montana Board of Water Well Contractors.
- 11. Since water withdrawn from the aquifers is not otherwise consumed, the water must be discharged in some matter. Any applicable water discharge permits must be obtained, and water disposal requirements must be met, before groundwater may be discharged, re-injected, or disposed in the Controlled Groundwater Area. Water discharge permits may include the Montana Pollutant Discharge Elimination System (MPDES) permit from the Department of Environmental Quality (DEQ), for discharge to surface water, and the Underground Injection Control (UIC) permit from the Board of Oil and Gas Conservation, for discharge re-injected to groundwater.
- 12. Extensive coal bed methane development has occurred from coal-bearing strata within the Powder River Basin geologic structure in Wyoming and some development has occurred in Montana near Decker. The Powder River Basin geologic structure and associated coal-bearing strata extends north into southeastern Montana. Consequently, coal bed methane development will likely extend further north into southeastern Montana in the near future.
- 13. The proposed controlled groundwater area includes the Wasatch Formation and the Tongue River Member of the Fort Union Formation. The formations are the two principle coal-bearing strata in southeastern Montana. The area forms a generally contiguous block of these coal-bearing formations within the Montana part of the Powder River Basin (see Map 1). According to the Montana Bureau of Mines and Geology (MBMG), the area includes all known strippable subbituminous coal deposits greater than 30 inches thick in southeastern Montana. (MBMG SP28, Figure 10).
- 14. Montanans have a right to a clean and healthful environment.

CONCLUSIONS OF LAW

- 1. Excessive groundwater withdrawals are very likely to occur in the near future because of consistent and significant increases in withdrawals from within the area proposed for controlled ground water designation. By "excessive", the Department means that water levels in targeted aquifers could be reduced near project areas for long periods of time in a water-scarce area.
- 2. The public health, safety, and welfare require that such extensive water withdrawals in a water-scarce area are monitored and the water withdrawals be controlled where existing beneficial uses of water are adversely affected. Without this designation of a controlled ground water area the extensive withdrawals of ground water anticipated may proceed uncontrolled.
- 3. With this designation of a controlled groundwater area the withdrawal of groundwater associated with coal bed methane production will be under the prior jurisdiction of the Montana Board of Oil and Gas. However, water rights matters and hydrogeologic issues are not within the ordinary technical expertise and area of concern to the Board. These are matters ordinarily dealt with by the Montana

- Department of Natural Resources and Conservation and the Montana Bureau of Mines and Geology. The Montana Department of Natural Resources may petition the Board for hearings in regard to the production, use, and disposal of water from coal bed methane development wells that could effect existing water rights in the area based upon information gathered concerning water withdrawals.
- 4. This controlled groundwater designation will not affect regulation of new water rights for conventional water uses. If local interests wish to acquire water rights to wells constructed during coal bed methane development, a beneficial use permit will be required. Standard exceptions to permit requirement will still apply. For example, a permit will not be required for appropriations of 35 gallons per minute or less and not exceeding 10 acre-feet per year on wells developed for beneficial use. Laws for ground water withdrawals that do not require a water use permit such as conventional oil and gas activities, mining, or agricultural drainage, will remain in effect as in other parts of the state.
- **5.** Discharges of water during coal bed methane development, and well sealing to prevent leakage and contamination are sufficiently regulated by the DEQ and Board of Oil and Gas.
- 6. The designation of a controlled groundwater area does not infringe on the rights of Montana citizens to a clean and healthful environment.

ORDER

The following described area, as also delineated on Map 1 attached, is designated a Controlled Groundwater Area under Mont. Code Ann. § 85-2-506: all sections in Township 06N, Ranges 45E and 46E; all sections in Township 05North, Ranges 40East – 47 East; all sections in Township 04 North, Ranges 38 East, 39 East, 41East – 46 East, and 48 East; all sections in Township 03 North, Ranges 37 East – 49 East; all sections in Township 02 North, Ranges 36 East – 50 East; all sections in Township 01North, Ranges 36 East – 50 East; all sections in Township 01 South, Ranges 37 East – 50 East; all sections in Township 02 South, Ranges 37 East – 51 East; all sections in Township 04 South, Ranges 37 East – 51 East; all sections in Township 05 South, Ranges 36 East – 50 East; all sections in Township 06 South, Ranges 36 East – 51 East; all sections in Township 07 South, Ranges 37 East – 51 East; all sections in Township 08 South, Ranges 37 East – 51 East; and all sections in Township 09 South, Ranges 37 East – 51

East. The controlled groundwater area includes all formations above the Lebo member of the Fort Union Formation.

1. Applicability to coal bed methane wells only.

This controlled groundwater area designation shall apply only to wells designed and installed for the extraction of coal bed methane (CBM).

2. Standards for Permitting, Drilling, and Producing Coalbed Methane Wells

CBM development within the controlled groundwater area must follow the standards for drilling, completing, testing, and production of CBM wells as adopted by the Board of Oil and Gas Conservation. Standards include: field development proposals including initial test wells and development plans; maps of the targeted coal bed; an inventory and hydrologic assessment of existing wells, springs, and streamflow that could be impacted by the operation; and means to mitigate water resource impacts. The Board of Oil and Gas Conservation shall consider applications for each coal bed methane production field. Approval of specific field rules may include requirements and restrictions in addition to the general operating standards.

3. Water Source Mitigation Contract

Coal bed methane operators must offer water mitigation agreements to owners of water wells or natural springs within one-half mile of a CBM field proposed for approval by the Board or within the area that the operator reasonably believes may be impacted by a CBM production operation, whichever is greater. This area will be automatically extended one-half mile beyond any well adversely affected. The mitigation agreement must provide for prompt supplementation or replacement of water from any natural spring or water well adversely affected by the CBM project and shall be under such conditions as the parties mutually agree upon. Mitigation agreements are intended to address the reduction or loss of water resources and may exclude mechanical, electrical, or similar loss of productivity not resulting from a reduction in the amount of available water due to production from CBM wells. The areas covered by mitigation agreements will be considered in review of field development proposals. The TAC will make recommendations to the Board of Oil and Gas Conservation if it identifies a need to increase the required mitigation area.

4. Technical Advisory Committee

The DNRC will designate a Technical Advisory Committee (TAC) with specific expertise in coal aquifer hydrology and shallow groundwater systems. The committee will oversee the groundwater characteristics and monitoring, and the reporting requirements identified in items 5 and 6 below. The TAC will also review groundwater data and scientific evidence related to the Powder River Basin Controlled Groundwater Area and advise the agencies on administration of the area.

The committee will consist of qualified scientists with experience related to the hydrogeology of coal aquifers and CBM extraction operations. The appointments and selections shall be to ensure, to the extent possible, that the committee includes members with expertise in hydrogeology, water quality, and CBM extraction systems and operations.

The TAC will periodically review groundwater data gathered from CBM development. This TAC will prepare an annual report each year, of their findings regarding the impact to the groundwater resource from CBM activities and any mitigation recommendations they may develop. The TAC may submit reports more often if they find it appropriate. Additionally, the TAC will make recommendations to the Board of Oil and Gas Conservation regarding development of specific groundwater characterization, monitoring, and reporting requirements for field developments.

5. Groundwater Characterization, Monitoring, and Reporting

Hydrologic conditions in the targeted coal beds must be assessed prior to field development to establish baseline conditions. Specific requirements of the field rules will dictate that groundwater pressure is monitored in appropriate locations using dedicated monitoring wells, and that groundwater monitoring and reporting is conducted in a manner consistent with the recommendations outlined in the attached memorandum (Attachment A). In addition to all forms required by the Board of Oil and Gas Conservation Completion, a Montana Well Log Report, DNRC Form 603, must be completed for both production and monitoring wells when the wells are drilled and sent to DNRC at the address on the form within 60 days of the well completion. The specific requirements for each production field will be developed with consideration of recommendations from the TAC. The procedures will include dedicated groundwater monitoring wells outside of, and surrounding the production field. The operator will be required to seek landowner approval to install such wells at appropriate distances from the field. State or federal lands should be considered. If the operator demonstrates that

no site is available at appropriate distance, a well at the extreme outer limit of the operator's lease area may suffice. Dedicated groundwater monitoring wells must be placed in the next aquifer above and below the targeted coal seam, if applicable, within the production field. Also, as a minimum requirement, at least one 24-hour aquifer test must be conducted using at least one observation well, and baseline groundwater pressures and water quality data must be obtained from the monitoring wells prior to production.

6. Data Collection and Notice Procedures

Data collected from testing and production of CBM wells and any groundwater monitoring wells and springs required by the Board of Oil and Gas Conservation will be available to the public and provided to the Montana Bureau of Mines and Geology. The Board of Oil and Gas Conservation will notify DNRC of applications relating to CBM field development proposals so that the Department may supply a mailing list of potentially affected water right holders within one-half mile of the proposed field area. The Board will publish notice in accordance with its existing procedures and will additionally require the developer to send individual notices to the water right holders listed by the DNRC.

NOTICES

1. Precautions in Coalbed Methane Areas

Water well developers and drillers must exercise caution when drilling water wells in or near coal bed methane projects as free methane gas may be encountered in one or more coal beds. Drillers should contact the Board of Oil and Gas Conservation Office at (406) 656-0040 for information about coal bed methane activities in their area of interest.

2. Beneficial Use of Water

Beneficial uses of water produced from CBM operations, such as for stock ponds, wildlife ponds, or irrigation requires a water right issued by DNRC as provided by law.

3. Water Discharge and Re-injection

The DEQ Water Protection Bureau at (406) 444-3080 administers the Montana

Pollution Discharge Elimination System permit. The Board of Oil and Gas Conservation at (406) 656-0040 administers the Underground Injection Control permit.

day of December 1999.

Dated this

Arthur Clinch, Director
Dept of Natural Resources and Conservation
1625 Eleventh Avenue
Helena, Montana 59620
(406) 444-2074

MEMORANDUM

The public hearings on the establishment of the Powder River Basin Controlled Groundwater Area were well attended and the Water Resources Division received substantial written comment. The public comment was unanimous in its concern that scarce water resources and existing water uses in the area be protected and overwhelmingly favored establishing a controlled groundwater area. The only dissent to the DNRC proposal did not object so much to the underlying goal of protecting the groundwater resource, but was more concerned that existing regulation was being duplicated.

Local public support for a controlled groundwater area is critical. The Powder River Basin situation is unique in its vast area, its water scarcity, the volume of withdrawals contemplated, and the immediacy of those withdrawals. The DNRC therefore initiated the process for establishing the area on its own motion rather than waiting for a local petition. If, however, it had appeared during the information-gathering period that the public was not interested in or did not favor establishing the area, the DNRC would not have gone forward with the proposal. After all, it is local water users that a controlled groundwater area is designed to protect.

The comment generally expressed concerns about a lack of information about the possible impacts of, and lack of government control and coordination over, water withdrawals and discharges during coal bed methane development. The DNRC has attempted to address these concerns with the modified findings, conclusion, and order.

The most important component of the modified order is the requirement to record and gather baseline and monitoring data so that problems and impacts can be detected as they occur. Of equal importance may be the establishment of a technical advisory committee to review, analyze, and make recommendations concerning the information gathered. The technical advisory committee can also review information provided by local water users. Judging from the public comment, the local land owners will be more than willing to provide any information they might have that will help the committee to track the impacts of the water withdrawals. Without such information and review, attempts to mitigate any adverse impact and to implement any necessary control over the development would be difficult. Individual water users generally do not have the resources to put together the information required to implement controls or mitigate impacts.

The modified order has also attempted to address concerns about the lack of coordination and duplication of regulation between government agencies. For example, the modified order recognizes the jurisdiction of the Montana Department of Environmental Quality over water discharges. The public comments expressed grave concern about the quality of the water and the DEQ has been apprized of that concern. The DNRC, however, will not be regulating in that area. It has also been determined that the Montana Board of Oil and Gas already has sealing standards for wells that will protect aquifers from contamination so that there is no reason to apply such standards as a condition of the controlled groundwater area.

One notable addition to the findings and conclusions concerns a Montana citizen's right to a clean and healthful environment guaranteed by Article II, Section 3 of the Montana Constitution. A recent Montana Supreme Court Decision, *Montana Environmental Information Center et al. v. Department of Environmental Quality,* 1999 MT 248, holds that the right to a clean and healthful environment is fundamental. Since water is vital, it would seem then that the Department would be remiss not to consider the environmental implications of establishing this controlled groundwater area. The Department believes that establishing the area will not intrude on the right to a clean and healthful environment, but rather will help to establish a means by which that right can be protected.

In conclusion, the DNRC was gratified by the interest and support expressed for the controlled groundwater area. When the community center in Broadus is filled to capacity

and a petition with over 150 signatures from that sparsely populated area is submitted it cannot be ignored. The DNRC will reciprocate by keeping the public informed of all developments. The DNRC also appreciates the attendance by Redstone Gas Partners at each of the public meetings and the cooperation they have shown throughout this process. The DNRC has considered the comments of all the participants and those comments have entered into the fashioning of this final order.

CERTIFICATE OF SERVICE

This certifies a true and correct copy of the Final Order was served upon all parties on the attached lists this _____ day of December 1999.

APPENDIX F MBOGC BOARD ORDER 99-99

MBOGC BOARD ORDER 99-99

IN THE MATTER OF THE BOARD'S OWN MOTION FOR
AN ORDER ESTABLISHING COAL BED METHANE
OPERATING PRACTICES WITHIN THE POWDER RIVER
BASIN CONTROLLED GROUNDWATER AREA IN BIG
HORN, POWDER RIVER, ROSEBUD, TREASURE AND
CUSTER COUNTIES, MONTANA.

BEFORE THE BOARD OF OIL AND GAS CONSERVATION

OF THE STATE OF MONTANA

IN THE MATTER OF THE BOARD'S OWN MOTION FOR
AN ORDER ESTABLISHING COAL BED METHANE
OPERATING PRACTICES WITHIN THE POWDER RIVER
BASIN CONTROLLED GROUNDWATER AREA IN BIG
HORN, POWDER RIVER, ROSEBUD, TREASURE AND
CUSTER COUNTIES, MONTANA.

ORDER NO 99-99

Docket 130-99

Report of the Board

The above entitled cause came on regularly for hearing on the 9th day of December, 1999, in the Billings Petroleum Club, Billings, Montana, pursuant to the order of the Board of Oil and Gas Conservation of the State of Montana, hereinafter referred to as the Board. At this time and place testimony was presented, statements and exhibits were received, and the Board then took the cause under advisement; and, the Board having fully considered the testimony, statements and exhibits and all things and matters presented to it for its consideration by all parties in the Docket, and being well and fully advised in the premises, finds and concludes as follows:

Findings of Fact

1. Due, proper and sufficient notice was published and given of this matter, the hearing hereon, and of the time and place of said hearing, as well as the purpose of said

hearing; all parties were afforded opportunity to present evidence, oral and documentary.

2. Current interest in developing coal bed methane reserves in the Powder River Basin has raised concerns about the effects of such development on groundwater in the area because production of such reserves will require dewatering the coal beds

3.

Order

IT IS THEREFORE ORDERED by the Board of Oil and Gas Conservation of the State of Montana that this general order applies to coal bed methane wells drilled on private and state land in the Powder River Basin Controlled Groundwater Area as established by the Department of Natural Resources and Conservation. It does not apply to lands owned by Indian Tribes or held in trust by the United States for Indian Tribes or individual Indians.

- 1. Applications for permit to drill exploratory wells to determine the potential for coal bed methane (CBM) production will be approved as wildcat gas wells under existing rules. Well density is limited to one well per section, setback at least 990 feet from the section lines. Locations must be advertised and the ten day waiting period prior to approval applies.
- 2. Wells drilled for the purpose of exploring for or producing CBM must meet the drilling, completion and plugging requirements of any other well under the Board's general rules and regulations. However, wells that are drilled to the top of the target coal and have casing set and cemented back to surface need not be equipped with a separate string of production casing.
- 3. Requests for temporary spacing units of less than 640 acres or for increased well density for a test pod of wells or for a "pilot" project of limited scope may be authorized by the Board after notice and public hearing. Notice of public hearing will be published by the Board in the manner customarily used by it; the applicant must provide actual notice of proposed hearing to the record owners as required under Section 82-11-141(4)(b), MCA, and to water right holders in the temporary spacing unit proposed for the pilot project.
- 4. An application for public hearing to establish permanent spacing and field rules for a CBM development project must include such information as is customarily required for establishment of well spacing and field rules for conventional gas production. Applicants must also present at the hearing a field development plan including maps, cross-sections and a description of the existing hydrologic resources, including water wells or springs that may be affected by the project, and a copy of the water mitigation agreement being

used or proposed for use in the project area. The applicant must provide an estimated time frame for development activities, a monitoring/evaluation plan for water resources in the project area, the proposed number and location of key wells which will be used to determine water levels and aquifer recovery data, and water quality information for target coal aquifers available at the time of hearing. The Board will publish its customary notice of public hearing; the applicant must provide actual notice as required in Section 82-11-141(4)(b), MCA, and must notify all record water rights holders within one-half mile of the exterior boundary of the proposed field area.

- 5. Notice to water rights holders must be given by mailing the written notice, postage prepaid, to the address shown by the records of the Department of Natural Resources and Conservation at the time notice is given. The notice must briefly summarize the application and provide the time and place of the public hearing.
- 6. Coal bed methane operators must offer water mitigation agreements to owners of water wells or natural springs within one-half mile of a CBM field proposed for approval by the Board or within the area that the operator reasonably believes may be impacted by a CBM production operation, whichever is greater. This area will be automatically extended one-half mile beyond any water well or natural spring adversely affected. The mitigation agreement must provide for prompt supplementation or replacement of water from any natural spring or water well adversely affected by the CBM project and shall be under such conditions as the parties mutually agree upon. Mitigation agreements are intended to address the reduction or loss of water resources and may exclude mechanical, electrical, or similar loss of productivity not resulting from a reduction in the amount of available water due to production from CBM wells. The Board will review areas covered by mitigation agreements as part of its review of field development proposals.
- 7. Coal bed methane production will be reported on Board Form No. 6 and will include produced volumes of both gas and water. Form No. 6 will be filed for all unplugged CBM wells even if the only production reported is water. An initial preproduction static water level will be reported for each newly completed CBM well at the time Form No. 4 is filed. For those wells designated as key wells, the operator will report an annual shut-in static fluid level following a shut-in period of at least 48 hours or such lesser time as is adequate to determine a stabilized level. For those wells designated as dedicated monitoring wells, a quarterly fluid level will be reported.
- 8. The requirement to run electric or radioactive wells logs will be met if the operator logs one well in each quarter section to the deepest target CBM horizon. The minimum log required is a gamma-ray log, which may be run through pipe; however, a gamma ray-density log in open hole is recommended.
- 9. Approval of development plans and establishment of field rules and spacing requirements will be under such conditions and time frames as the Board may deem adequate.

Done and performed by the Board of Oil and Gas Conservation of the State of Montana at Billings, Montana, this 9th day of December, 1999.

BOARD OF OIL AND GAS CONSERVATION

	OF THE STATE OF MONTANA
	Dave Ballard, Chairman
	Denzil Young, Vice-Chairman
	George Galuska, Board Member
	Jack King, Board Member
	Allen Kolstad, Board Member
	Stanley Lund, Board Member
	Elaine Mitchell, Board Member
ATTEST:	
Terri Perrigo, Executive Secretary	,

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